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California Energy Commission
Proposed EPIC Interim Investment Plan 2021

Introduction

The Electric Program Investment Charge (EPIC) Program was established by the California Public Utilities Commission (Commission, CPUC) in 2011 to fund technology research to support California in meeting its clean energy goals, with a focus on providing ratepayer benefits, including reliability, lower costs, and safety. The program has provided substantial benefits to the state, including the following examples:[1]

- Sixty-five percent of technology demonstration and deployment project funding to research in and benefiting low-income or disadvantaged communities.
- Commercialization of more than 34 technologies and related service companies.
- Contribution to the ability of companies funded by EPIC research to collectively receive over $2.2 billion in private investment and follow-on funding.
- Research that has improved the effectiveness of energy-related codes and standards. Five such research projects could lead to over $1 billion in annual energy cost savings if adopted into regulatory codes.

Funding for the EPIC Program was initially authorized until December 31, 2020. In 2019, the Commission initiated a proceeding to renew EPIC Program funding. In the first phase of the proceeding, completed on September 2, 2020, the Commission renewed the EPIC Program for an additional 10 years, which will consist of two, five-year investment cycles. The Commission approved the CEC as a continued program administrator and authorized a budget of $147.26 million per year for the first

1 CEC, April 17, 2020, Opening Brief of the California Energy Commission to the Phase 1 Issues Identified in the Assigned Commissioner's Scoping Memo and Ruling, Rulemaking 19-10-005, https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M335/K836/335836752.PDF. Note: The amount reported here for private investment and follow-on funding was updated by CEC staff and reported at the EPIC Virtual Symposium in October 2020.

investment cycle of January 1, 2021 through December 31, 2026 (referred to as EPIC 4). In the second phase of the proceeding, the Commission is evaluating administrative changes to the EPIC Program.

The Commission recognized that the CEC may need funding to begin work on new EPIC projects until a full EPIC 4 Investment Plan can be developed with public and stakeholder input and approved by the Commission. With the EPIC 4 Investment Plan due in October 2021, and a few months for the Commission to consider it, approval is not expected until early 2022. An Interim Investment Plan, as allowed by the Commission in the Phase 1 Decision, would enable the CEC to continue to fund projects critical to maintaining research momentum and helping achieve the state's clean energy goals faster, providing benefits to ratepayers, and providing economic stimulus to support economic recovery. This appendix is the CEC's Interim Investment Plan (Interim Plan). The Interim Plan includes a set of research initiatives that build on the previous EPIC 3 Investment Plan and are focused on a limited set of specific, near-term needs that can feasibly be pursued through EPIC-funded projects for the first year of EPIC 4. The full EPIC 4 Investment Plan will include a more diverse set of research initiatives shaped by the additional stakeholder outreach afforded by the full plan development cycle (for example, multiple public workshops, targeted stakeholder vetting of initiatives by CEC and the Commission).

Research Themes and Policy Priorities

Because this plan is anticipated to cover only the first year of EPIC 4[2] and had a much shorter development window, the scope and extent of the research initiatives here are more limited than those in a full investment plan. The research themes in this plan are described in this section and aligned to key state policy priorities as illustrated in Table 1. Equity considerations are discussed within the proposed initiatives.

2 January 1, 2021 through December 31, 2021.

The CEC's overall approach to advancing equity in the development of the plan was to build on what we have learned through engagement to date through meetings, workshops,[3] past research projects, and input from project technical advisory committees, as well as input from recent equity-related reports. These include meetings with the Disadvantaged Communities Advisory Committee (DACAG) EPIC subcommittee;[4] Policy + Innovation Coordinating Group (PICG) Equity Workstream meetings;[5] and recommendations from sources such as the California Environmental Justice Alliance (CEJA) *Environmental Justice Agency Assessment* and the Greenlining Institute's *Making Racial Equity Real in Research*.

Several proposed initiatives are outgrowths of current projects and have been articulated as under-resourced community priorities such as sustainable/affordable housing and community resilience. These initiatives include dedicated funding (25 percent minimum up to 100 percent) to under-resourced communities.

Other initiatives have statewide applicability but will require inclusion of benefits for under-resourced communities (e.g., the value of resilience initiative). To amplify the benefits of research projects intended to increase equitable access to new and emerging clean energy technologies, the CEC has heard several messages that inform our program implementation. Communities do not want to be an afterthought in projects and should be meaningfully engaged throughout project implementation. Often there is information overload and information provided is not always relevant to their interests so information should be curated and targeted. Priority should be given to cultivating relationships and partnerships that help communities to more actively

3 CEC held an Environmental Social Justice Roundtable with community leaders and advocates on Dec 10, 2019 and received input on EPIC, specifically on the Entrepreneurial Ecosystem.
4 Met with the DACAG EPIC subcommittee on December 7, 2020; presented draft initiatives and received feedback on the ones that were of highest interest and suggestions to improve relevance; and incorporated their input into the initiatives.
5 Information on the PICG is posted on the CPUC website https://epicpartnership.org/.

participate in research projects. Finally, communities expressed a need for additional training on EPIC. The CEC has implemented a four-pronged Equity Strategy:

1. Increase awareness of EPIC and the opportunities it provides under-resourced communities;
2. Encourage technology/project developers to seek out projects in under-resourced communities;
3. Scope many solicitations around specific issues facing ratepayers in under-resourced communities; and
4. Embed equity in clean energy entrepreneurship.

One mechanism that will empower active community-based organization (CBO) engagement is the inclusion of scoring criteria in Technology Development and Demonstration solicitations that require the project team to have active, substantive input and partnerships with CBOs. Projects need to do more than simply be located in an under-resourced area. Applications must consider the localized health impacts and project benefits. Importantly, solicitations require inclusion of CBOs as paid project partners who expand community engagement through traditional and digital methods.

The CEC is planning to escalate equity engagement for the full EPIC 4 Investment Plan, due to the CPUC in October 2021. We welcome input on how to best reach and incorporate input from interested communities and organizations. As an initial launch, we have an Energy Equity Outreach proposal; but before proceeding, part of our development process is to engage the DACAG EPIC subcommittee to gather input before finalizing a formal outreach plan. Outreach will include Empower Innovation Events proposed as using a networking "getting-to-know-you" session format with a moderator facilitating small group discussions and opportunities to meet virtually one-on-one. The goal is to enable communities to communicate their clean technology priorities, connect with technology developers as potential project partners, and profile host sites within their communities for clean energy technology projects. The outcome will be a directory of community-desired research projects that can feed into the

Empower Innovation Platform to facilitate project match-making and accelerate funding for some of these projects.

Table 1: Interim Investment Plan Research Themes Align to State Policy Priorities and CPUC Proceedings

Research Theme	Key State Policies[6]	CPUC Proceedings[7]
Decarbonization	Senate Bill (SB) 350 (Stats. 2015, ch. 547)	R.17-07-007
	Assembly Bill (AB) 758 (Stats. 2009, ch. 470)	R.19-01-011
	SB 100 (Stats. 2018, ch. 312)	R.13-11-005
	AB 2137 (Stats. 2014, ch. 290)	R.15-03-010
	SB 1477 (Stats. 2018, ch. 378)	R.13-09-011
	AB 3232 (Stats. 2018, ch. 373)	R.18-12-006
	SB 676 (Stats. 2019, ch. 484)	R.13-02-008
	AB 2127 (Stats. 2018, ch. 365)	R.18-07-003
	SB 32 (Stats. 2016, ch. 249)	R.20-08-022
	SB 1383 (Stats. 2016, ch. 395)	R.20-08-20
	SB 1369 (Stats. 2018, ch. 567)	
Resilience and Reliability	AB 1482 (Stats. 2015, ch. 603)	R.14-08-013
	AB 2514 (Stats. 2010, ch. 469)	R.14-10-003
	AB 2868 (Stats. 2016, ch. 681)	R.20-05-003
	SB 100 (Stats. 2018, ch. 312)	R.17-07-007
	SB 1339 (Stats. 2018, ch. 556)	R.17-09-020

6 See https://leginfo.legislature.ca.gov for more information.
7 See https://apps.cpuc.ca.gov/apex/f?p=401:1:0 for more information.

Research Theme	Key State Policies[6]	CPUC Proceedings[7]
	SB 1369 (Stats. 2018, ch. 567) SB 246 (Stats. 2015, ch. 606) SB 350 (Stats. 2015, ch. 547) SB 379 (Stats. 2015, ch. 608) SB 901 (Stats. 2018, ch. 626)	R.18-07-003 R.18-07-033 R.19-01-011 R.20-08-020 R.20-01-007
Entrepreneurship	SB 100 (Stats. 2018, ch. 312) SB 96 (Stats. 2013, ch. 356) AB 327 (Stats. 2013, ch. 611) SB 350 (Stats. 2015, ch. 547) SB 32 (Stats. 2016, ch. 249) AB 2514 (Stats. 2010, ch. 469)	

Decarbonization

Achieving California's climate goals will require phasing out the combustion of fossil fuels, or decarbonization. For the building, industrial, agriculture, water, and transportation sectors, this requires incorporation of high levels of energy efficiency and use of zero-carbon fuels. Meeting the state's climate goals in the next 30 years requires scaling up and using market-ready technologies, as well as advancing performance and reducing cost of promising technologies that have not been commercially proven.[8] In addition, decarbonization must be done in an equitable manner to ensure benefits also

8 Mahone, Amber, Zachary Subin, Jenya Kahn-Lang, Douglas Allen, Vivian Li, Gerrit De Moor, Nancy Ryan, Snuller Price. 2018. Deep Decarbonization in a High Renewables Future: Updated Results from the California PATHWAYS Model. California Energy Commission. Publication Number: CEC-500-2018-012.

accrue to under-resourced communities (e.g., disadvantaged, low-income communities,[9] and Native American tribes).

Low-income households spend a larger portion of their income on energy bills and need affordable housing options that are comfortable, healthy, and energy efficient. California residents' average annual energy costs (electricity and natural gas) are more than $1,500/year,[10] and costs are typically higher for those using wood pellets or propane for heating. In addition to this, housing in California remains some of the most expensive in the country with the average median purchase price of a home at more than $700,000 as of November 2020. In 2017, the median rent in California was at $1,358/month.[11] To help achieve California's greenhouse gas (GHG) reduction goals and reduce electricity bills, the CEC plans to invest EPIC funds to increase the efficiency, affordability, and resiliency of electric homes and include on- or near-site solar photovoltaic (PV) systems and energy storage.

On an annual basis, California's industrial sector consumes over 25 percent of the state's electricity and 35 percent of its natural gas; and is responsible for more than 20 percent of the state's GHG emissions.[12,13] The industrial sector is heavily dependent on natural gas for processing raw materials to finished products. However, with technology advancements there is the potential that some industries can convert some processes

9 *Disadvantaged communities* are those designated pursuant to Health and Safety Code section 39711 as representing the 25 percent highest-scoring census tracts in California Communities Environmental Health Screening (CalEnviroScreen) Tool 3.0. https://calepa.ca.gov/envjustice/ghginvest/. *Low-income communities* are those within census tracts with median household incomes at or below 80 percent of the statewide median income or the applicable low-income threshold listed in the state income limits updated by the California Department of Housing and Community Development (HCD). https://www.hcd.ca.gov/grants-funding/income-limits/state-and-federal-income-limits.shtml.

10 https://www.nytimes.com/2020/11/30/realestate/california-housing-market-price.html

11 State of California Draft 2020-2024 Federal Consolidated Plan; HCD. https://www.hcd.ca.gov/policy-research/plans-reports/docs/state_of_california_draft_2020-2024_federal_consolidated_plan_whopwa_with_memo.pdf.

12 California Energy Consumption Database – Staff estimate from 2016 dataset.

13 "Optionality, flexibility & innovation pathways for deep decarbonization in California". Energy Futures Initiative. 2019. https://energyfuturesinitiative.org/s/EFI_CA_Decarbonization_Full-b3at.pdf.

from gas to electric, improve the energy efficiency of their processes, and avail themselves of load reduction strategies to provide flexibility to the grid. As most industrial facilities are located in under-resourced areas, decarbonizing these facilities can result in jobs being maintained while reducing environmental impact. To help reduce GHG emissions in this sector, the CEC plans to target cold storage facilities. Many cold storage facilities are located in under-resourced communities and are associated with food processing and distribution or commercial/retail facilities. These facilities have the potential for increasing efficiency of its cooling systems while also providing demand response and grid flexibility. A 2015 LBNL study indicated that refrigeration warehouses are well-suited for demand response because of their high-power demand, thermal mass of the stored products, and insensitivity to short-term power reductions. Research innovations in cold storage facilities can help reduce electricity bills in this economically vital sector and help California achieve its clean energy and decarbonization goals at the same time.

As stated in the 2019 Integrated Energy Policy Report (IEPR), eliminating emissions from the transportation sector is critical to the state's clean air goals.[14] Emissions from transportation and associated production and refining of fossil fuels account for more than half of California's GHG emissions.[15] Transportation contributes the majority of smog-forming NOx emissions and is a significant contributor of other toxic air contaminants that negatively impact the health of all Californians.[16] In 2020, Governor Newsom accelerated work to reduce pollution from the transportation sector by setting a bold new target: "by 2035, all new cars and passenger trucks sold in California will be zero-emission vehicles."[17] EPIC focuses on transportation electrification that facilitates

14 Final 2019 IEPR Chapter 3 "Advancing Zero-Emission Vehicles." https://efiling.energy.ca.gov/getdocument.aspx?tn=232922.
15 California Air Resources Board (CARB) GHG Inventory 2020 Edition. https://ww2.arb.ca.gov/ghg-inventory-data.
16 CARB 2020 Draft Mobile Source Strategy. https://ww2.arb.ca.gov/sites/default/files/2020-11/Draft_2020_Mobile_Source_Strategy.pdf.
17 Executive Order (EO) N-79-20, https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-text.pdf.

EV growth, while maintaining or improving grid stability. Also, advancing electric vehicle (EV) charging and vehicle-to-building/vehicle-to-grid technologies to realize the potential for millions of new EVs may allow for enhanced load flexibility for California's grid.

Resilience and Reliability

There are conflicting definitions of resilience and how it relates to, and differs from, reliability, as discussed in the CPUC Microgrid Proceedings and associated staff white papers.[18] Although some ambiguity and overlap remain, CEC staff used the following conceptual definitions for discussing EPIC interim research initiatives:

- *Resilience* investments advance technologies, knowledge, and strategies to plan for, manage through, and recover from *large-area or long-duration outages.*
- *Reliability* investments advance technology, knowledge, and operational strategies that reduce the frequency or impact of *small-scale or short-duration disruptions* in electric service.

Some technologies supported by EPIC can contribute both to increased resilience and reliability. For example, continued advancements are needed for application and commercialization of microgrids that provide both reliability and resilience support to high-priority critical facilities and community emergency centers when protection at the local level is more appropriate and cost effective than larger grid upgrades.

Increasing the resilience and reliability of California's electric system and the critical services it provides customers remains a theme of EPIC research investments, the importance of which was reinforced by recent events. In August 2020, a historic heat storm in the Western United States challenged the ability of imported and in-state generation resources to meet net peak demand in California, contributing to the state's

18 (R.19-09-009) https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M344/K038/344038386.PDF.

first rolling blackouts in more than a decade.[19] Through November 2020, wildfires burned more than 4.7 million acres across California—more than double the total area burned in 2018—and eleven of the top-20 largest wildfires have occurred in recent years.[20] Climate change is bringing more frequent extreme heat storms, wildfires, and associated public power safety shutoffs (PSPS) that pose growing threats to resilient and reliable electricity in California.[21]

Research, development, and demonstration (RD&D) efforts focused on catastrophic and large-scale events, such as wildfires and sea-level rise, strengthen California's electric system and customer resilience. For example, advancements in climate science and near- and long-term forecasting of wildfire-related risks to electric infrastructure will be critical for informing planning and hardening investments in changing conditions. Technology advancements in distributed energy resources that can provide zero-emission back-up power to homes and public buildings during grid outages can support critical services and limit the damage caused by outages.

Similar advancements are required to develop technologies and strategies that increase electric system reliability at low cost while achieving Senate Bill 100 (SB 100) (De León, 2018) targets for 100-percent zero-carbon retail electricity sales. Preliminary modeling suggests California may require approximate 50 gigawatts (GW) of storage capacity by 2045 to provide the flexibility necessary to maintain reliability.[22] Increasing deployment and participation of flexible load in residential, commercial, and industrial sectors can be one of the lowest cost strategies for increasing reliability, although in the long-term new

19 Preliminary Root Cause Analysis Report, http://www.caiso.com/Documents/Preliminary-Root-Cause-Analysis-Rotating-Outages-August-2020.pdf.
20 CalFire. Stats and Events. https://www.fire.ca.gov/stats-events/. Accessed December 2, 2020.
21 Bedsworth, Louise, Dan Cayan, Guido Franco, Leah Fisher, Sonya Ziaja. (California Governor's Office of Planning and Research, Scripps Institution of Oceanography, California Energy Commission, California Public Utilities Commission). 2018. Statewide Summary Report. California's Fourth Climate Change Assessment. Publication number: SUMCCCA4-2018-013. https://www.energy.ca.gov/sites/default/files/2019-11/Statewide_Reports-SUM-CCCA4-2018-013_Statewide_Summary_Report_ADA.pdf.
22 SB 100 Preliminary Results. https://efiling.energy.ca.gov/getdocument.aspx?tn=234549.

technologies will be needed. For example, offshore wind energy (OSW) development is a promising resource available for California that can support increased reliability due to its complementary generation profile. Similarly, innovations in green electrolytic hydrogen and other forms of long-duration energy storage capable of discharging electricity for 10 to 100 hours will be critical for maintaining reliability.

Special attention is given in the initiatives for investments to under-resourced communities that are particularly vulnerable to service disruptions.

Entrepreneurship

Clean energy innovation has emerged as an important economic sector in California. For example, California is home to 107 of the 318 energy-storage technology companies in the United States and attracts more than 51 percent of all venture capital in the United States for clean energy innovation. Because of the economic impacts of COVID-19, private sector investors are expected to continue the significant reduction in new investments for even the most promising clean energy start-up companies. This will leave a funding shortfall that will likely put many of these companies out of business and slow further progress of clean energy innovation previously advanced by the state's significant investment.

In addition, the loss of these clean energy start-up companies could set California's clean energy policy goals back several years. Large energy corporations have mostly forgone in-house research and development (R&D) activities,[23] making the energy sector reliant on the start-up sector to introduce new technology solutions to the market. Instead of conducting their own R&D, large energy companies have found it more cost effective and opportunistic to strategically partner with or acquire start-up companies with new technology solutions than to develop their own. For example, Enel X and EDF Renewables, subsidiaries of two large global energy corporations, acquired EPIC-funded startups eMotorWerks and PowerFlex respectively to include new smart

23 IEA (2020), Clean Energy Innovation, IEA, Paris https://www.iea.org/reports/clean-energy-innovation.

EV-charging products and services in their business offerings. Boeing HorizonX Ventures, the venture investment arm of Boeing, led a strategic investment in EPIC-funded Cuberg, Inc., a Bay Area start-up company developing an advanced lithium-metal battery cell that greatly increases both energy density and safety compared to the best lithium-ion batteries currently used in EVs and energy-storage systems.

Without a prospering portfolio of clean energy start-up companies to partner with, large energy corporations will have to develop and scale up their own internal R&D activities as well as build-up their internal capacity and expertise to deploy these new technology products: a timeline that can take several years or more and at a risk profile most large companies are not willing to accept or likely to pursue. As a result, California's energy sector will be unable to introduce new technology solutions needed to continue transforming the electricity sector to be more resilient, affordable, and emissions-free in the necessary timeline.

Research Initiatives

This section describes the nine proposed research initiatives in this interim investment plan. Table 2 below provides an overview of research initiative topics and the themes addressed by each. Subsequent sections are dedicated to describing the background and details of each initiative.

Table 2: Research Initiatives and the Themes They Address

Research Initiative	Decarbonization	Resilience and Reliability	Entrepreneurship
1. Advanced Prefabricated Zero-Carbon Homes	X	X	
2. Energy Efficiency and Demand Response in Industrial and Commercial Cold Storage	X	X	
3.Energy Efficiency and Load Shifting in Indoor Farms	X	X	

Research Initiative	Decarbonization	Resilience and Reliability	Entrepreneurship
4. Optimizing Long-Duration Energy Storage to Improve Grid Resiliency and Reliability in Under- resourced Communities	X	X	
5. The Role of Green Hydrogen in a Decarbonized California—A Roadmap and Strategic Plan	X	X	
6. Valuation of Investments in Electricity Sector Resilience		X	
7. Vehicle-to-Building for Resilient Back-up Power	X	X	
8. OSW Technologies	X	X	
9. Entrepreneurial Ecosystem	X	X	X

1. Advanced Prefabricated Zero-Carbon Homes

Description

This initiative aims to develop zero-carbon or near-zero-carbon (collectively "ZC"), cost-effective, modular and manufactured homes (collectively "prefabricated homes") that can be readily deployed, particularly in under-resourced communities (e.g., disadvantaged communities, low-income communities, and Native American tribes). Requirements would be identified to determine the most advanced and cost-effective ZC prefabricated homes. Potential requirements include: 1) meet or exceed California's 2019 Title 24 Building Energy Efficiency Standards;[24] 2) be all-electric; 3)

24 Manufactured homes must meet the U.S. Housing Urban Development efficiency standards, which are less efficient than California's Building Energy Efficiency Standards. This initiative will

be fire-resistant; 4) use on-site, or near-site solar PV; 5) have on-site or near-site stationary energy storage; 6) provide back-up power to critical loads during grid outages; and 7) have a price point below the median price point per square foot for site-built homes in the county where the homes are to be located.

Selected prefabricated home builders would design and construct prefabricated ZC residential units. Eligible building categories include single-family units, accessory dwelling units, and migrant or agricultural worker housing. The built homes will be sited in under-resourced communities. Fire-prone communities are eligible to participate.

Anticipated Impact

Projects under this initiative could develop a model for other prefabricated home builders for homes that are ZC, fire-resilient, and energy-resilient at a price point that would be affordable to low-income residents in the community. The research results could inform the CPUC's Building Decarbonization Proceeding (R.19-01-011) by creating a new building decarbonization solution. Additionally, the results could assist the Wildfire and Natural Disaster Resiliency Rebuild Program by offering a template for all-electric, energy-resilient, and fire-resilient homes.

The initiative would have persistent benefits. Recommendations resulting from the research would be pursued through appropriate codes and standards organizations and through voluntary participation by builders to adopt methods of construction that produce more efficient, high-performance, and cost-effective buildings. These improved methods could serve as targets for utility incentive programs to further encourage diffusion into the manufactured building industry or other programs such as California Advanced Homes Program, California's Building Energy Efficiency Standards, and other standard-setting organizations.

require that manufactured homes meet or exceed California's standards. Modular homes are required to meet California's Building Energy Efficiency Standards. This initiative will require that these homes exceed the minimum California standards.

The electricity grid would benefit from the enhanced potential for these homes to shift load to off-peak periods; reduce net load due to efficient design, on-site solar PV, and energy storage; and provide ancillary services. If the research is successful, the end result would be ZC homes with renewable energy and energy storage that are affordable from an ownership and operation perspective, can provide resilience in the event of a power outage, and achieve low energy costs and higher comfort for residents compared to standard construction.

Primary Users and Beneficiaries

Residential building developers and designers, prefabricated home industry, residents in fire-prone communities, under-resourced communities, electric and natural gas ratepayers, utilities, and state and local governments.

Metrics and Performance Indicators

- Number of prefabricated home builders that adopt methods of construction that produce more cost-effective, high-performance, and energy-resilient ZC homes
- Number of ZC prefabricated home models available in the California market as well as other states[25]
- Number of high-performance prefabricated homes that are below the median price point per square foot for site-built homes in the county where the homes placed in under-resourced communities are to be located
- Number of ZC prefabricated home models available in California that include fire-resilient design features

25 California has 17 prefabricated manufacturing plants in California. Some of these plants ship homes outside of California.

Value Chain[26]	**Program Area(s)**
Demand-side management Generation	Technology demonstration & deployment

Background

This initiative focuses on prefabricated homes, which are homes built in a factory setting, including manufactured and modular homes. The aim is to increase the efficiency, affordability, and resiliency of these homes by efficient design and technologies; and adding on-site, or near-site solar PV and storage. The focus is to demonstrate projects located in under-resourced communities. Potential home elements include the following:

- Decarbonization: Inclusion of advancements in energy-efficient, all-electric construction, including use of high efficiency, low global-warming potential (low-GWP) refrigerant heat pumps; and building envelopes, including air tightness, that meet or exceed current building energy efficiency codes and minimize GHG emissions.
- Fire Resiliency: The need for fire-resilient homes is growing as intense and longer wildfire seasons become the norm in California. This research considers new construction practices, techniques, and materials that can be implemented in buildings located in fire-prone communities to withstand massive, wind-driven flames and embers—including ignition-resistant roofs and exteriors, tempered windows, unvented attics and soffits, and back-draft dampers.
- Energy Resiliency: PSPS can leave communities and essential facilities without power, which poses risks to vulnerable communities and individuals. Integrating

26 Per the CPUC's 2/10/2012 EPIC Staff Proposal "In general, staff suggests the activities should be able to be mapped to the different elements of the electricity system "value chain" which we characterize as consisting of: Grid Operations/Market Design, Generation, Transmission, Distribution, Demand Side Management. … this mapping ensures that there is a clear relationship between the activities funded by EPIC and the electricity ratepayers who are ultimately paying for this program." (https://docs.cpuc.ca.gov/EFILE/rulc/159429.pdf)

solar and energy storage technologies with prefabricated home units would provide back-up power during grid outages.

- Affordability: "Affordable housing cost" for lower-income households is defined in state law as not more than 30 percent of gross household income with variations (Health and Safety Code Section 50052.5). Less than a third of Californians can afford a median-priced home.[27] This research initiative challenges prefabricated home manufacturers to build homes that are affordable to own and operate for those living in under-resourced communities.
- Reliability: Uncontrolled electric space conditioning and water heating contribute to peak demand. Incorporating load flexibility controls and advanced envelope design features into prefabricated homes will allow for daily load shifting from peak to off-peak periods and allow homes to be pre-cooled during extreme heat events.

The two types of prefabricated homes this research initiative focuses on include manufactured homes and modular homes.

- **Manufactured homes**: These homes are built on steel chassis and transported to the site. The destination of these homes are mobile home parks and private lots. These homes are built quickly and more affordably in a factory setting compared to standard construction. However, these manufactured homes only need to meet the U.S. Housing Urban Development's efficiency standards, which are less energy efficient than the California 2019 Title 24 Building Efficiency Standards.[28] As a result, ratepayers in this sector, who are often in under-

27 https://www.car.org/marketdata/data/haitraditional.
28 EIA 2008. Residential Energy Consumption Survey. http://www.eia.doe.gov/emeu/recs/contents.html. Washington, D.C. US Department of Energy.

resourced communities, pay twice as much in energy costs (per square foot) than those who live in homes that are built to Title 24 Standards.[29]

- **Modular homes**: These homes are created in sections and then transported to the home site for construction and installation. These are typically installed and treated like a regular house for financing, appraisal, and construction purposes. Although the sections of the house are prefabricated, the sections or modules, are put together at the construction site. These homes are required to meet California's Title 24 Building Efficiency Standards. Modular construction enables home customization to include standardized energy-efficiency measures; therefore, it can serve as a path to increased ZC-home penetration. Modular construction can be used to create a tight building envelope, well-insulated and air-sealed, to downsize the heating, ventilation, and air-conditioning (HVAC) systems and reduce overall building energy consumption and construction costs compared to standard construction. An affordable ZC home can potentially be achieved if this is combined with high-efficiency appliances and renewable generation.

Research Themes and Policy Priorities Addressed

This initiative falls under the themes of **decarbonization** and **resilience and reliability**. Key policy priorities that may be addressed by the proposed research are discussed below.

Building Decarbonization. Current 2019 Title 24 Standards do not achieve the ZC statewide goal set by Executive Orders B-55-18 and B-30-10.[30] This initiative aspires to

29 EIA 2008. Residential Energy Consumption Survey. http://www.eia.doe.gov/emeu/recs/contents.html. Washington, D.C. U.S. DOE.

30 Executive Order (EO) B-55-18 (Establishing a new statewide goal to achieve carbon neutrality as soon as possible, no later than 2045, and achieve and maintain negative emissions thereafter); EO B-30-15 (Establishing a new interim statewide GHG emission reduction target to reduce emissions to 40 percent below 1990 levels by 2030, to ensure California meets its target of reducing emissions to 80 percent below 1990 levels by 2050).

assist in reaching this goal by developing affordable ZC home designs and buildings that can concurrently fulfill the CEC's Residential New Construction Zero Net Energy Action Plan and low-income and disadvantaged community resource requirements.[31] In January 2019, the CPUC instituted a new rulemaking on building decarbonization (R.19-01-011). The proposed scope of the rulemaking includes: 1) implementing SB 1477 (Stern, 2018); 2) potential pilot programs to address new construction in areas damaged by wildfires; 3) coordinating CPUC policies with California's Building Energy Efficiency Standards and Title 20 Appliance Efficiency Standards developed at the CEC; and 4) establishing a building decarbonization policy framework. This initiative would help inform this rulemaking through building and demonstrating ZC homes that are all-electric, energy-efficient and resilient, and that can be installed in areas damaged by wildfires.

GHG emissions from buildings represent a significant portion (25 percent) of statewide emissions.[32] By reducing the amount of energy needed in buildings through energy-efficient design, replacing on-site combustion appliances with high-efficiency heat pumps, and reducing the carbon content of energy resources (e.g., solar PV), this research initiative aspires to achieve the following:

- Reduce GHG emissions;
- Improve both indoor and outdoor air quality; and
- Reduce health risks from buildings.

Resilience and Reliability. These homes would include solar PV, storage, and potentially demand-response controls to provide energy resilience. The solar PV and energy

31 Residential New Construction Zero Net Energy Action Plan (It supports the California Energy Efficiency Strategic Plan's goal to have 100 percent of new homes achieve zero net energy beginning in 2020 and provides a foundation for the development of a self-sustaining zero net energy market for new homes.). California Energy Efficiency Strategic Plan, 2008, adopted by the CPUC in D. 08-09-040 and the 2011 update, adopted in D. 10-09-047. www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/eesp.
32 https://ww2.arb.ca.gov/our-work/programs/building-decarbonization.

storage system will be designed to provide power to essential building loads in the event of a power outage. Demand-response (DR) controls can also be used to provide regular reliability support under normal grid conditions and to reduce electrical loads during periods when the grid is stressed, thus increasing grid reliability.

Previous Research

This initiative builds on previous research as discussed below.

- In 2017, the CEC completed a research project focused on pilot-testing advanced envelope designs for the manufactured housing industry and how to provide high-performance, cost-effective alternative envelope designs to factory homebuilders.[33] This project demonstrated advanced building envelope technologies are cost-effective, commercially-viable, and offer new manufactured home buyers a compelling value proposition: to pay a little more upfront but enjoy lower monthly energy bills and other benefits. The focus was manufactured homes, and the advanced envelope designs were offered as an option to potential homebuyers by participating manufactured housing industry representatives.[34]
- Following the results from the 2017 study, in 2020, the CEC awarded two EPIC grants focused on advanced building envelopes for all-electric manufactured homes. The CEC received more applications and passing proposals than available resources could fund. This research initiative would build on this solicitation by including other energy-efficiency advancements along with solar PV and energy storage to contribute to fire resilience, energy resilience, and affordability, and would include prefabricated modular homes. Like the 2020 solicitation, continuing

33 PIR-12-028: Advanced Envelope Systems for Factory Built Homes.

34 Advanced Envelope Systems for Factory Built Homes, Publication Number CEC-500-2019-007, California Energy Commission Publication Database.

elements would include fire resiliency, building envelope energy efficiency, and GHG reductions.[35]

- The CEC's BRIDGE and CalSEED programs discussed near the end of this Research Initiatives Section have produced advanced technologies for manufactured homes. These technologies can be evaluated; and if ready for larger-scale deployment, the technologies can be included in the home design. Example technologies could include advanced heat pumps and windows with PV.
- The U.S. Department of Energy (DOE) has targeted research toward highly efficient and productive construction practices for new buildings and retrofits. This includes development of new building materials, new methods of fabrication (such as use of 3D printing), robotics, and digitization and off-site manufacturing. The construction practices include those for standard and modular construction and manufactured housing. The projects focus on manufactured housing and evaluating the cost-effectiveness of various technologies through improved techniques. For instance, U.S. DOE's Building Technologies Office's 2019 Advanced Building Construction Initiative invested $33.5 million in new technologies that included innovations in construction technology, improving quality and affordability, increasing competitiveness among buildings, and developing a skilled building and retrofit workforce. The goals are high building performance, quick deployment with minimal on-site construction time, and buildings that are affordable and appealing to owners, investors, and occupants. The focus of many of these projects was to achieve deep energy savings and greater lifecycle affordability and included manufactured homes, such as modular and mobile homes. The CEC would leverage U.S. DOE's research and focus on innovative construction technologies.

Key Technical and Market Challenges

35 EPC-19-035: Advancing Energy Efficiency in Manufactured Homes Through High Performance Envelope; and EPC-19-043: Advanced Energy-efficient and Fire-resistive Envelope Systems Utilizing Vacuum Insulation for Manufactured Homes.

Market Penetration Challenges. The most common prefabricated homes in California are manufactured homes. To date, highly efficient and zero net carbon manufactured homes have failed to gain market traction due in part to the need to minimize upfront capital costs to homeowners. As most manufactured home purchasers have limited incomes, any increase in home cost could limit their ability to secure financing.[36] Most construction companies and factory homebuilders are not incentivized to develop manufactured homes with energy-efficient designs that meet or exceed state or federal requirements or provide on-site energy generation. Energy-efficient features are typically treated as "options." With increased investment in these homes, economies of scale may be achieved, lowering the cost and perceived risk to stakeholders.

Developing Business and Technical Case for Zero Net Carbon or Low-Carbon Manufactured Homes. The typical ownership and tenant relationship in mobile home parks presents difficult design issues to achieving ZC mobile homes. Generally, manufactured homes are owned by their occupants, who lease (pay rent on) land that is owned by another entity where their homes are located. These homes generally cannot accommodate rooftop solar PV due to their size, weight, and structural requirements. Innovation in manufactured home or mobile home park design is needed to incorporate solar PV and energy storage and address existing electrical infrastructure. There is a need for scalable and replicable business and technical cases addressing the challenges facing many manufactured home occupants and mobile home park owners. Once performance is validated, these solutions can be available as options to purchasers of manufactured homes and mobile home park developers, if permitted by the Department of Housing and Community Development.

Equity Considerations

To ensure equity in the EPIC Program's investments, this initiative will be exclusively in under-resourced communities, including an option for fire-prone areas. Highly efficient

36 PIR-12-028: Advanced Envelope Systems for Factory Built Homes.

prefabricated homes can result in more comfortable and energy-efficient single-family homes that are also more cost-effective to own and operate and faster to build.

2. Energy Efficiency and Demand Response in Industrial, Agricultural, and Commercial Cold Storage

Description

This funding initiative aims to develop and deploy innovative energy-efficiency technologies for cost-effective decarbonization and DR participation of cold-storage facilities. The advancements would increase DR participation, while allowing food industries, agricultural businesses, and emerging online grocers opportunities to utilize more cost-effective and reliable cold storage. Example technologies and strategies include:

- Advanced refrigeration systems
- Artificial intelligence-based software and controls
- Advanced coatings to reduce defrost times
- Use of low-GWP refrigerants
- Innovative moisture control methods to reduce cooling load (such as desiccant dryers, evaporators, or other energy-efficient means)
- Thermal energy storage and controls to enable grid flexibility and participation in DR programs
- Deployment of smart control systems and software to optimize system performance to increase energy efficiency, reduce operation and maintenance costs, reduce GHG emissions, and identify system refrigerant leaks and other equipment performance issues that impact equipment lifespan
- Cost-effective retrofits of existing, old facilities

Thermal storage technologies can act as a capacitor for maintaining the temperature of large, refrigerated spaces for long periods. With the recent advancements in phase-changing materials and controllers, cold-storage facilities can potentially increase their thermal storage and further enhance their ability to participate in shifting and fine-tuning their cooling loads. Advanced surface coatings have the capability to increase the life of condensers by keeping moisture off the fins and preventing ice buildup. Ice buildup increases the system run time as well as the energy required to run defrost cycles. System performance may also be improved by adding dryers to air intakes, which decrease the air's humidity through chemical processes; thus, this enhancement can further reduce the cooling load and increase the life of components in moist environments.

Anticipated Impact

Assuming an annual electricity use of 1 terawatt-hour (TWh), or an average continuous load of 114 megawatts (MW), projects in refrigerated warehouses are expected to increase efficiency by at least 10 percent. With a 30-percent market penetration, it is estimated that cold-storage facilities would save 30 GWh annually. For demand response projects, with an estimated 20-percent peak-load shift and a 30-percent market penetration, there is potential to shift 6.8 MW of the average 114-MW load.

Primary Users and Beneficiaries

This research on cold storage would provide the food, beverage, and other industries and customer-facing commercial cold-storage facilities (such as grocery stores) with the potential to improve energy efficiency, reduce GHG, and provide grid flexibility.

Metrics and Performance Indicators

- Electrical energy savings (percent)
- Avoided/reduced Maintenance costs ($)
- Increased system efficiency (Coefficient of Performance)
- Load-shift potential (kilowatt [kW]/time)
- Increases in cooling capacity (British thermal units)
- Savings for the delivered end product ($)
- GHG savings (metric tons of carbon dioxide equivalent)
- Decrease in defrost intervals (time)

Value Chain	Program Area(s)
Demand-side management	Technology demonstration & deployment

Background

On an annual basis, California's industrial sector consumes over 25 percent of the state's electricity and 35 percent of its natural gas; and is responsible for more than 20 percent of the state's GHG emissions.[37,38] This sector is vital to California's economy, accounting for 10 percent of its GDP[39] in 2019, and it depends on affordable, reliable, and sustainable energy supplies.

Decarbonization of industrial systems and services can create several benefits for Californians, including improved air quality, reduced GHG emissions, and significant cost savings. Decarbonization is often performed through the substitution of natural gas with electricity as well as increasing the energy efficiency of production processes to reduce electricity or natural gas use. Furthermore, the widespread adoption of energy management system software can help ensure that equipment is operated efficiently to reduce GHG emissions without sacrificing equipment performance or product quality.

Refrigeration accounts for an estimated one-third of the total energy usage for food-processing facilities, while additional energy is used for intermediate cold storage at warehouses and at commercial retail locations. The CEC estimates that refrigerated warehouses and grocers used more than 5 TWh of electricity for refrigeration annually, with refrigerated warehouses accounting for 1 TWh of the total.[40] The state currently has nearly 400 million cubic feet of cold-storage space and demand for additional cold-

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37 California Energy Consumption Database – Staff estimate from 2016 dataset.
38 "Optionality, flexibility & innovation pathways for deep decarbonization in California". Energy Futures Initiative. 2019. https://energyfuturesinitiative.org/s/EFI_CA_Decarbonization_Full-b3at.pdf.
39 Bureau of Economic Analysis – U.S. Department of Commerce 2019 Third Quarter Dataset.
40 California Energy Commission demand forecast intermediate data, 2013

storage facilities is increasing due to online grocery sales.[41] Grocers are investing more heavily in their supply chains and e-commerce capabilities to reduce transit and delivery times. That is fueling the development of more cold-storage facilities, especially in densely populated areas where more people are demanding faster deliveries of fresh food. Jones Lang LaSalle IP, Inc. said the average U.S. cold-storage warehouse is more than 40 years old. Companies who rent cold-storage space prefer newer buildings with more energy-efficient cooling systems and higher ceilings that can pack bigger volumes,[42] reducing operational costs. Newer cooling systems have the capability to keep product temperatures between a smaller temperature range, increasing shelf life and thus profits.

Hydrofluorocarbons (HFCs) can be up to 1,430 times more damaging to the environment than CO_2 and can remain in the atmosphere for 15 years or more. In the U.S., there has been a 269-percent increase in HFCs since 1990. Commercial and industrial refrigeration applications including air conditioning are responsible for 48 percent of HFC emissions in California.[43]

Today, distributed demand-side resources play a growing role in distribution and transmission grid management. DR can help smooth a renewables-heavy grid by shifting load away from the high-ramp periods, raising the belly of the "duck curve" to limit renewable curtailment, and balancing variable generation with the help of smart communicating technologies both behind the meter and on the grid. With round-the-clock operations of energy-intensive processes, the industrial and commercial refrigeration sectors can further help California decarbonize by incorporating DR into processes and facilities capable of providing flexibility.

41 Borland, K.M. California is the Top Market for Cold Storage, June 2019, https://www.globest.com/2019/06/17/california-is-the-top-market-for-cold-storage/?slreturn=20201003214341
42 Fung, Ester, "The Hot New Real-Estate Investment is in Keeping Food Chilled", Wall Street Journal, October 6, 2020.
43 California Air Resources Board, "Appendix C: California SLCP Emissions", November 2016, https://ww2.arb.ca.gov/sites/default/files/2020-07/SLCP_Appendix_C.pdf.

In 2015 Lawrence Berkeley National Laboratory (LBNL) analyzed the potential research in DR for the refrigeration sector. They found that refrigeration warehouses are well-suited to shift or shed electrical loads in response to utility financial incentives and were selected as one of the foci of LBNL's energy efficiency and DR research because:

- They have significant power demand, especially during utility peak periods.
- Refrigeration loads account for a significant portion of the facilities' total energy usage.
- Most refrigeration loads are not sensitive to short-term (two to four hours) power reductions, so DR activities are often not disruptive to facility operations.
- The thermal mass of the stored product in the insulated spaces can often tolerate reduced cooling capacity for a few hours when needed.
- Past experience with some DR strategies that were successful in commercial buildings may apply to refrigerated warehouses.[44]

Research Themes and Policy Priorities Addressed

Energy efficiency, advanced controls, and energy management systems in the industrial and commercial refrigeration sectors would help those sectors with **decarbonization** by reducing electricity consumption and increasing use of low-GWP refrigerants. DR in refrigeration addresses **resilience and reliability** by aiding grid reliability and stability. Also, DR helps California transition from fossil fuels to intermittent renewables as the state decarbonizes.

Previous Research

Several past and current EPIC R&D efforts have focused on advanced technologies to increase efficiency in the refrigeration sector. Projects range from demonstrating systems that utilize low-charge ammonia, reduce potential leakage of refrigerants, and increase efficiencies, such as developing an advanced booster ejector system, which

44 Aghajanzadeh, Arian, "2006-2015 Research Summary of Demand Response Potential in California Industry, Agriculture, and Water Sectors", CEC, 2015.

recovers waste heat and enhances overall heat pump efficiencies. For DR, EPIC has funded systems capable of shifting their electrical load by a minimum of 20 percent and anticipated to achieve up 30 percent. The control strategies enabled by projects such as these have also increased system operability and allowed plant managers an easier way to manage and control their equipment.

In recent years, EPIC R&D has focused on improving the efficiency of industrial energy-related systems, such as compressed-air systems, by demonstrating software programs that benchmark and compare existing operations with industry standards and then identify opportunities for reducing energy use. Project results for cloud-based energy management of compressed-air systems for 102 demonstration sites showed total energy savings of 20,406,000 kWh/year and 5,775 tons/year in avoided GHG emissions. Forty percent of the sites were in the food and beverage manufacturing industry; however, no refrigerated warehousing and storage sites participated. More research is needed to understand energy savings and benefits across more diverse industries and to develop data sets to generate industry baselines for cold-storage industries.

Key Technical and Market Challenges

Despite the advancements described above, the adoption of previously funded general research and small-scale demonstrations remains an obstacle for several reasons. Before adopting an energy-efficient improvement, a facility must be convinced the improvement will maintain or improve product quality. California's food and beverage manufacturers have historically operated on small profit margins; equipment capital costs are high and need high levels of justification; and installation must not significantly disrupt manufacturing or jeopardize profit margins. As a result, to facilitate adoption, dissemination of successful research results will be key to showcase the technology's technical and economic performance, benefits, and any impacts on product quality.

In more recent years, online food retailers are growing at a massive rate and are transitioning to warehouse storage for quicker, more economical solutions to delivering food. The influx of new businesses will create new challenges for the refrigeration sectors, requiring innovative solutions to match the demand and maintain current systems while meeting California's electric grid challenges and climate and decarbonization goals.

Major equipment replacements are costly and disruptive. The industrial and agricultural sectors are very much attuned to economics and cost. Equipment replacements typically happen infrequently, and any downtime results in production decreases and revenue losses. Returns on investments must be below three years to justify high equipment costs and require strong examples of technology fully implemented in a similar application to minimize risk.

The industrial and agricultural sectors are risk averse. Demonstrations are needed to show that energy savings and benefits are achievable and sustainable while maintaining or improving product quality.

Equity Considerations

One of the target areas of this initiative would focus on projects in under-resourced communities, where many cold-storage facilities are located. This initiative has the potential to reduce operation and maintenance costs, which will help cold-storage facilities remain competitive, keep jobs in California, and help the bottom line. Some of these jobs could come to individuals from under-resourced communities.

3. Energy Efficiency and Load Shifting in Indoor Farms

Description

The purpose of this initiative is to demonstrate advancements in energy efficiency and load shifting in indoor farms. Indoor farms include conversion of existing buildings into indoor farms and retrofits of existing greenhouses that can achieve the following:

- Improve electrical efficiency, reduce water use, and increase yield;
- Reduce GHG emissions
- Develop potential to shift load of operations;
- Expand potential for growing high-value crops (such as berries and other fruits, mushrooms, herbs, leafy greens, etc.) in an urban setting; or
- Expand potential for growing food closer to the point of processing or consumption to further reduce energy usage associated with transport.

This initiative focuses on demonstrating pre-commercial technologies, hardware systems, control systems, and operational procedures of a digitized indoor farm that would increase energy efficiency and develop the potential to shift load. Potential pre-commercial technologies or strategies may include (but are not limited to) the following:

- Optimized layout, type, and operation of farm to reduce energy use per unit of product
- Data acquisition and energy management system
- Combination of natural and advanced artificial lighting, high-efficiency HVAC, and dehumidification systems and controls to reduce overall electrical energy use
- Hardware and software to enable DR and load flexibility
- Modular farm concepts that could be easily deployed with a limited urban footprint to reduce energy use and GHG emissions associated with crop production and transportation of the crops to the end-user

Anticipated Impact

Intensive vertical farms can consume 8,700 to 70,000 megawatt-hours per year (MWh/year) of electricity, while a shipping container farm might consume 45 MWh/year. Projects are expected to increase efficiency by at least 10 percent, providing savings up to 700 MWh/year for large facilities, and provide DR capability to shift daily electrical load by at least 20 percent.

Primary Users and Beneficiaries

Energy-efficiency projects would help the indoor farm's bottom line and provide farmers with the potential to improve energy efficiency, reduce GHG, and provide grid flexibility. Customers in under-resourced communities could benefit from wider availability of fresh produce.

Metrics and/or Performance Indicators:

- Electrical energy usage and savings (kWh/square feet)
- Water usage and savings (gallons [gal] water/square feet)
- Product yield per area (lbs./square feet)
- Product yield per energy use (lbs./kWh)
- Product yield per water use (lbs./gal)
- DR or load-shift capabilities of facility (kW shifted)
- Net cost of product produced ($/lbs.)

Value Chain	Program Area(s)
Demand-side management	Technology demonstration & deployment

Background

California is home to a vibrant and diverse agricultural sector where the value of the 2019 crop year was over $50 billion, making it the top agricultural producing state in the United States. To produce California's vegetable, fruit, and nut crops, over 11 TWh is used annually for irrigation. Indoor farming has potential to reduce water use by over 70 percent, providing a potential for substantial electricity reduction for water pumping, although this reduction is offset by the energy requirements for lighting and environmental control.

Indoor farms producing high-value crops typically are heated, cooled, and lighted 24 hours a day, seven days a week. Through the optimization of indoor-farm operations, development and deployment of advanced, energy-efficient technologies, and optimization of crop yield versus energy usage, there is opportunity for electricity savings, especially in the areas of lighting technologies, space conditioning, and smart controls. Though recent advances in light-emitting diode lighting reduced indoor farming's energy use by about 80 percent, there is still potential for further reductions. Much of the energy is used during times when renewable energy is unavailable, such as at night and during the evening ramp. Load shifting for indoor farming requires understanding impacts of underwatering, reduced lighting, and changes in climate control on plant health and potential yields throughout the lifecycle.

Indoor farming has the potential to reduce transportation and energy use associated with distribution if indoor farms are located near the point of processing or consumption. Currently, in the United States, most of the fresh produce is shipped extensive distances (in some cases between 1,500 and 2,500 miles) from the field to the consumer. Billions of dollars are spent annually delivering and distributing crops from where they are grown to where they are sold, consumed, or processed. Studies have shown that long-distance transport can result in fresh vegetables and fruits losing a portion of their nutrition and freshness. Unless preservatives are used, long-distance shipment reduces the shelf life of the produce once it reaches the warehouse or store. Reduced shelf life leads to additional spoilage and waste. It was reported in 2008 that approximately $47 billion worth of food in the U.S. (which includes meat, dairy, produce, and other products) did not make it into consumers' shopping carts due to waste.[45]

45 Buzby, Jean C. and Jeffrey Hyman. "Total and Per Capita Value of Food Loss in the United States." Food Policy, 37(2012):561–570

Research Themes and Policy Priorities Addressed

Decarbonization. Energy efficiency, advanced controls, and energy management systems in indoor agriculture would help the sector decarbonize by reducing electricity consumption.

Resilience/reliability. Electric load shifting in indoor farms can reduce consumption during grid stress and reduce outages.

Previous Research

Past and current EPIC research objectives in agriculture focused on precision irrigation and use of software controls to: increase the efficiency of irrigation and participation in DR programs; and assess whether these approaches could optimize water use and energy management while providing grid flexibility. One project developed a data analytics software platform that monitors irrigation pumps, energy rates, and other parameters to send alerts to growers on how and when to irrigate. The project demonstrated the ability to reduce water and energy usage by 9 percent and 15 percent, respectively, without affecting crop yield or quality. Similar approaches could be used to optimize the lighting, environmental controls, and water use in indoor farms to reduce energy usage based on plant growth and development lifecycles.

Key Technical and Market Challenges

Despite the advancements described above, the adoption of previously funded research and small-scale demonstrations remains an obstacle for several reasons. Before adopting an energy-efficient improvement, a facility must be convinced the improvement will maintain or improve product quality. California's farmers have historically operated on small profit margins; equipment capital costs are high, and they need confidence that changes will not jeopardize their profit margins.

The COVID-19 pandemic has sparked demand for urban agriculture due to farmers struggling to supply food to markets as a result of labor shortages and sharp shifts in demand that have forced them to dump crops.[46] Avoiding such logistical problems is one of the chief advantages to growing food closer to population centers with indoor farms.

Major equipment replacements can be costly and disruptive. Returns on investments typically should be below three years to justify equipment costs and potential down time in an industry that operates in an emerging market with typically slim profit margins. Investors may be hesitant to spend money on advanced technologies with long payback periods in the current market.

Equity Considerations

This initiative targets demonstrating indoor farms in under-resourced communities. In addition to the demonstrations, this initiative can include job training and education to residents in these communities on optimizing the energy efficiency and operations of these farms to reduce energy and operational costs, such that the benefits can also be realized by other indoor farms that were not part of projects funded by this initiative. Retrofitting empty warehouses or commercial buildings in under-resourced communities could create local jobs and serve as a template for other development projects in the community and elsewhere.

46 Despommier, Dickson, "Vertical Farms fill a Tall Order", Wall Street Journal, July 25, 2020.

4. Optimizing Long-Duration Energy Storage to Improve Grid Resiliency and Reliability in Under-resourced Communities

Description

This initiative would demonstrate the increased resilience that clean long-duration energy storage systems can provide to critical facilities[47] in under-resourced communities. The proposed projects from this initiative would also take into consideration the potential risks of power outages from extreme weather conditions and wildfire mitigation plans while targeting under-resourced communities.

Climate change is contributing to extreme weather events, such as wildfires and heat waves, which are affecting the grid's ability to provide continuous power to customers. In the last few years, California's electrical grid experienced considerable challenges from wildfires, resulting in a greater application of PSPS. Additionally, the extreme heat events in 2020 resulted in rolling blackouts over two days in August. The impact on under-resourced communities can be significant, as back-up power options may be too costly, and when diesel is used as a backup, local air quality is negatively impacted.

This initiative would demonstrate how critical community facilities can modulate facility demand, energy storage output, and renewable power to achieve optimal resiliency. Demonstrations would couple smart inverters, energy management systems, or a microgrid controller, in concert with energy storage, and document the strategies that best meet performance needs for critical loads while minimizing cost.

Long-duration energy storage offers a clean alternative to back-up diesel generators. Additionally, if the energy storage has long enough duration, it would allow critical

47 Critical operations include any that, if interrupted, will cause a negative impact on a community's ability to safety operate business activities. Such impacts range from significantly hindering the management of community functions and losing revenue key to local community activities to the loss of life. Critical facilities include, but are not limited to, nursing homes, hospitals, and police, fire, and community emergency-response installations.

facilities in under-resourced communities with high risk factors of power outages to endure PSPS events and other grid power-loss events. Over the last 3 to 5 years, long-duration energy storage technologies have advanced significantly, and there are many emerging technologies that can provide enough energy storage protection to manage through ("ride out") many of these power-loss events.

In 2020, the EPIC Program invested in seven different energy-storage research and demonstration projects that are anticipated to demonstrate 10 hours or more of energy-storage duration. Some of these projects are in under-resourced communities. With additional research and some system improvements, these emerging technologies can provide 14-16 hours of protection, and when matched with a renewable system like solar, the combined system can provide these critical facilities as many as 24-36 hours of protection. The last few years of experiencing these grid outage events throughout California have shown that having at least 24 hours of protection can result in the most critical facilities being able to manage through these power outage events and continue to provide necessary services to their residents.

Anticipated Impact

This initiative would increase customer resilience in under-resourced communities with high risk factors of power outages and demonstrate how these facilities can rely on clean renewables and energy storage to protect the community during unexpected grid outages. The proposed projects will take into consideration improvements anticipated in utilities' climate mitigation plans and General Rate Cases (GRCs). If successful, adoption would be realized in other communities throughout the state. Critical facilities would not have to rely on polluting, noisy back-up diesel generation systems, or worse yet, have no back-up power available.

Primary Users and Beneficiaries

Primary beneficiaries are the participating communities, and the lessons learned would encourage non-participating communities to deploy similar arrangements.

Research results will be available to communities and organizations representing under-resourced communities, CPUC, California Independent System Operator (California ISO), CEC, utilities, independent power producers, energy-storage developers, vendors, and service providers, U.S. DOE, national labs, California Energy Storage Association, Energy Storage Association, researchers, and policy makers.

Metrics and Performance Indicators

- Measurable improvement on resilience targeting under-resourced communities with high risk of power outages
- Survey community satisfaction with performance meeting critical loads
- Measured, repeatable ability to provide 24 hours of continuous and uninterrupted back-up protection to critical facilities during an actual or simulated power outage event
- Polluting emissions eliminated from reducing or eliminating operation of fossil-fueled back-up generators to provide the same level of outage protection
- Ability to serve critical loads such as refrigeration, exit lighting, and medical equipment for full duration of outage by optimizing storage, generation, and control strategies
- Improved business cases for longer duration energy storage in under-resourced communities

Value Chain	Program Area(s)
Grid operations/market design	Technology demonstration & deployment
Demand side management	

Background

During the Northern California PSPS events in October 2019, over 2 million individuals and operations were impacted by grid-outage events. The average outage was more than 11 hours. Many critical facilities that did have a clean battery back-up system did not have enough storage to manage through the entire event. Many critical and sensitive patients in care homes and other medical facilities had to be moved to new locations or shelter in place without power. Decarbonization of the electric, gas, and transportation energy systems as California transitions toward a low-carbon energy future will require sustained record-breaking deployment of solar and renewable generation coupled with energy storage.

The majority of installed energy storage within California's electrical system is based on pumped hydroelectric storage and lithium-ion batteries. There are limited opportunities for further large-scale deployment of pumped hydroelectric storage in California. Lithium-ion technology will be a significant part of California's energy future; however, it does not have the cost or performance capabilities to meet all of California's energy storage needs, and a diversified portfolio of energy-storage technologies is required to achieve SB 100 goals. Compared to lithium-ion and pumped hydroelectric storage, alternative energy storage technologies (such as alternative battery chemistries, flow batteries, solid-state batteries, fly wheels, thermal energy storage, hydrogen technologies, etc.) may offer longer duration storage at lower cost, longer system lifetimes, improved safety, thermal runaway immunity, environmental benefits, and energy and system net-efficiency benefits.

Projections from the CPUC in their Integrated Resource Plan show that the state will need almost 9 GW of energy storage and an additional 1 GW of long-duration energy storage by 2030. To meet this goal, the state currently projects that lithium-ion energy storage will be selected for the majority of these energy storage systems and pumped hydroelectric energy storage will be used for long-duration energy storage for the next few years. While these technologies are currently the most available systems, by 2030, new and emerging energy-storage technologies will meet some of these future needs with better performing and lower cost systems. The studies developed as part of the implementation of SB 100 show that California will need between 25 and 40 GW of new energy-storage systems and an additional 3-4 GW of long-duration energy storage by 2045 to ensure the future grid can operate reliably and safely. This research effort could help ensure the state has a portfolio of energy-storage options that includes short-term and long-duration energy-storage systems and can select the best, most cost-effective solutions to meet various application needs.

Research Themes and Policy Priorities Addressed

This initiative supports the **resilience and reliability** theme. Energy resilience is supported by storing energy in a battery or alternative energy-storage technology for use on demand. An energy-storage system connected to a residence, retailer, commercial building, critical facility, or connected directly to the utility, provides the ability to store energy and manage through variations in renewable generation and electrical power outages. Longer duration energy storage is required to meet the multi-hour to multi-day energy resiliency needs associated with PSPS events. These events are triggered depending on location and site-specific conditions such as temperature, terrain, and local climate. SB 901 requires electric utilities to develop annual wildfire mitigation plans to prevent, combat, and respond to wildfires within their service territories.

Emerging energy storage technologies based on different material compositions such as zinc, sodium, nickel and other materials are showing promise in being able to provide energy storage durations in the 10 to 20 hour range. Energy storage systems based on inexpensive thermal storage materials, compressed air systems, and pumped hydro are showing the potential to provide energy storage durations of several days to as long as a week; energy storage systems based on these materials are undergoing early stage development and demonstration. These new and emerging energy storage systems need the opportunity to demonstrate their performance and cost competitiveness in real-world applications to make the transition to commercial viability.

Energy storage is one of the technologies that can help ensure a future reliable, low-GHG, 24/7 energy supply. By advancing energy storage technologies that reduce reliance on backup diesel generators during energy outages, this initiative also supports the **building decarbonization** theme.

Previous Research

Over the last decade, the cost of solar has decreased by over 95 percent, and the cost of energy storage has decreased by over 80 percent. These costs are expected to continue to decrease in the future, making these technology solutions more affordable to end customers. Over the last decade, the CEC has invested in more than 50 energy-storage research projects representing more than 15 different emerging energy-storage technologies. These investments have allowed these technology companies to improve performance attributes and lower cost. In 2020 alone, the CEC awarded over $53 million in new energy-storage research grants to 22 recipients. Including more than $45 million in awardee match funding, this represents the largest investment in emerging energy-storage technology advancements in the history of the CEC. This investment is helping address the key market challenge facing emerging energy storage: allowing new and emerging energy-storage technologies the opportunity to demonstrate their capabilities in real-world applications.

Key Technical and Market Challenges

Today, lithium-ion energy-storage technologies dominate California's new energy-storage deployments. However, lithium-ion technology is normally designed for 3-5 hours of duration and does not have the desired cost, safety, or performance capabilities to meet all of California's longer duration energy-storage needs. Additionally, with the growth of the stationary energy storage market and the expansion of the electric vehicle market, lithium-ion based systems are expected to have challenges sourcing the materials needed meet all their future demands. A diversified portfolio of energy-storage technologies is required to achieve SB 100 goals. However, most alternative energy-storage technologies are largely pre-commercial and public-sector funding is required to support these technologies through early commercialization. Many of these new energy storage technologies have emerged in the last few years as the interest in energy storage solutions has grown substantially globally. The new and emerging technologies provide the promise of lower cost, safer designs, longer lifetimes, and more environmentally friendly materials; however, they have not been built, demonstrated, and tested at a scale needed to support the rapidly growing market in California.

These emerging energy-storage technologies need to address the next major challenge of being able to provide long-duration energy-storage capabilities of 10 hours to 100 hours of back-up power support at a cost that is competitive with the current alternatives. None of these technologies have reached these goals yet, but many are on a path to reach or exceed the goals in the future. The state needs to continue to support these emerging energy storage technologies with additional demonstration projects so they can make a successful transition to truly commercial products. The greatest challenge will be accelerating the commercialization of these alternative energy-storage technologies fast enough for them to be able to provide a significant contribution to reaching California's 2045 energy goals. Being able to demonstrate the ability to provide 24-36 hours of clean backup that does not rely on any fossil fuel system is the next major technology hurdle to cross. Not only must they work safely, reliably, and at a competitive price, but they must demonstrate the ability to instill confidence in the end customer that they will work when called upon the first time and every time needed. This performance must be achieved to enable widespread replacement of fossil fuel based backup systems.

Equity Considerations

This initiative is targeted to the needs of under-resourced communities and demonstrations will be sited exclusively in under-resourced communities. The projects funded through this initiative will identify under-resourced communities with high risk of power outages and apply and demonstrate clean long-duration energy-storage technologies to improve local resilience. California is experiencing a surge in the deployment of diesel-fueled back-up generators in stark contrast to state air-quality and energy goals. Clean, long-duration energy-storage systems will help reduce air pollution from diesel emission and improve air quality by reducing the need for, and provide an alternative to, diesel-fueled generators. This effort is extremely critical to the under-resourced communities that are exposed to higher levels of air pollution.

5. The Role of Green Hydrogen in a Decarbonized California—A Roadmap and Strategic Plan

Description

This initiative would analyze green hydrogen and make recommendations on its role in meeting the zero-carbon goals of SB 100 by 2045. Green hydrogen is defined in SB 1369 as "hydrogen gas produced through electrolysis and does not include hydrogen gas manufactured using steam reforming or any other conversion technology that produces hydrogen from a fossil fuel feedstock." It offers a unique capability to be a major emerging technology that could play a key role in the carbon-free energy sector of California's future. The challenge is that green hydrogen is currently much more expensive than grey or blue hydrogen.[48] The technical and research challenge is to reduce the cost of green hydrogen.

Detailed technical analysis needs to be completed for each energy sector to assess how green hydrogen compares to other technical alternatives for each of the potential uses. Additionally, an understanding of the compounding benefit and cost-reduction impact of multiple sectors relying on green hydrogen could result in an accelerated implementation schedule. However, as a nascent technology, there are many fundamental questions to be explored before committing significant research investments. Questions include:

- How much of the energy-storage capability planned for the state should be green hydrogen?

48"Grey hydrogen" is produced from fossil fuels by steam reforming of natural gas, partial oxidation of methane, and coal gasification. "Blue" hydrogen is a cleaner version where the carbon emissions are captured and stored or reused. Renewable energy is used to produce green hydrogen through water electrolysis. (https://www.californiahydrogen.org/resources/hydrogen-faq/#S32). Cost estimates for producing grey and blue hydrogen from natural gas are compared on a regional basis in the IEA publication: "Hydrogen production costs using natural gas in selected regions, 2018, IEA, Paris" (https://www.iea.org/data-and-statistics/charts/hydrogen-production-costs-using-natural-gas-in-selected-regions-2018-2).

- What is the capacity need for seasonal energy storage that green hydrogen could be well-suited to address?
- What are the highest value uses of green hydrogen?
- If green hydrogen is implemented significantly in one sector, does the transition to hydrogen in another sector become more cost-effective over alternative technology options? How can this synergy be maximized by co-location or other strategies?

A roadmap prepared under this initiative would address these questions and inform potential research initiatives in the CEC's EPIC 4 Investment Plan.

Anticipated Impact

This initiative would provide a unique opportunity to research and report on the possible applications and uses of green hydrogen. As stated above, green hydrogen has the potential to become a key emerging technology to help California meet future planned decarbonization goals, especially in sectors with few other viable options. Most of the current information provided by the industry on the use of green hydrogen is potentially biased, as the projections are developed by technology producers. An unbiased analysis, from a neutral point of view, will ensure policy makers and future planners have the actionable information available to help them make this important transition.

The state will develop its first implementation plan addressing the key elements needed to transition and meet the goals of SB 100 in 2021. This green hydrogen initiative would develop a roadmap to inform the second iteration of the SB 100 implementation plan.

Primary Users and Beneficiaries

Key beneficiaries for this research include the CPUC; California ISO; CEC; utilities; independent power producers; energy-storage developers; EV developers, vendors, and service providers; U.S. DOE; national labs; California Energy Storage Association; Energy Storage Association; researchers; and policy makers developing their plans to meet the established state climate goals. The long-duration energy-storage, transportation, and the renewable generation sectors could benefit from understanding the cost to transition to green hydrogen applications when compared to other emerging and existing technologies.

Metrics and Performance Indicators

The measurable metric would be the number of citations to the roadmap as an indicator of its value to policy makers, research planners, and the industry. The roadmap would include performance metrics to evaluate the ability of green hydrogen to:

- Compete with alternative long-term energy-storage technologies on cost ($/MW) and performance (capacity, safety, duration and life expectancy).
- Calculate if co-locating green hydrogen significantly lowers cost per MW.
- Calculate the cross-sector cost reduction benefit of green hydrogen supporting multiple market segments (generation, grid reliability, transportation, industrial/agricultural decarbonization) in meeting future SB-100 goals.

Value Chain	**Program Area(s)**
Grid operations/market design Generation	Applied research & development

Background

Currently, approximately 95 percent of world-wide hydrogen is produced from fossil fuels by steam reforming of natural gas, partial oxidation of methane, and coal gasification.[49] This type of hydrogen is commonly called "grey hydrogen." A cleaner version is "blue" hydrogen, where the carbon emissions are captured and stored, or reused with carbon capture and storage. When renewable energy is used to produce green hydrogen, through water electrolysis, the entire process can be 100-percent emission-free.

49https://www.californiahydrogen.org/resources/hydrogen-faq/#S32

One area receiving specific attention in California is hydrogen fueling stations. SB 1505 (Lowenthal, 2006) requires that 33.3 percent of the hydrogen dispensed at stations receiving state funds in California come from renewable energy sources. This bill requires all stations, regardless of funding source, to be 33.3-percent renewable once a certain volume threshold is reached. The Low Carbon Fuel Standard Hydrogen Refueling Infrastructure Program requires that participants (station owners) dispense at least 40-percent renewable hydrogen content on weighted average.[50] Two hydrogen fueling station owners, FirstElement Fuel and Shell, have both reported that they have supply agreements in place for 100-percent renewable hydrogen at their stations.[51] These programs will advance the use of green hydrogen, expand the market, and lower the future costs of green hydrogen. Green hydrogen is a technology with applications for long-term energy storage, fuel switching for power plant generation, and decarbonization. Additionally, as California continues to push for more OSW generation, the potential for excess renewable generation could increase as these OSW systems are expected to have a much higher capacity factor then onshore wind systems and create an ideal environment for the large-scale generation of green hydrogen. SB 1369 calls for the CEC to "consider green electrolytic hydrogen an eligible form of energy storage, and to consider other potential uses of green electrolytic hydrogen." Additionally, in 2021, the state will develop its first plan on the key elements needed to transition and meet the goals of SB 100.

Research Themes and Policy Priorities Addressed

This initiative supports the **resilience and reliability** and **decarbonization** themes. Resilience is addressed as hydrogen enables large amounts of energy to be stored over long durations, providing energy resilience in the event of an electrical power outage.

50 https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf

51 Joint Agency Staff Report on Assembly Bill 8: 2019 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California. https://ww2.energy.ca.gov/publications/displayOneReport_cms.php?pubNum=CEC-600-2019-039

Electrical system reliability can be enhanced by using hydrogen as an energy carrier to distribute and store large amounts of energy for responding to normal variations in renewable generation.

Previous Research

Over the last five years, the CEC has researched the technology applications of green hydrogen. Initial research was focused on hydrogen fuel-cell applications and hydrogen as energy storage. In 2018, the state chaptered SB 1369, which requested the CEC to research additional applications of green hydrogen. In 2020, the CEC awarded three new grants to hydrogen technology companies to demonstrate applications of green hydrogen as energy storage that will improve the resilience and reliability of the utility grid. Additionally, the CEC completed a year-long study[52] on the vast variety of potential uses and applications of green hydrogen for all energy sectors and identified the key obstacles, barriers, and challenges to commercializing green hydrogen. The research provides an excellent baseline for understanding the roles green hydrogen could play in the future decarbonization of the state's energy sectors.

The U.S. DOE "Hydrogen Program Plan"[53] updates and expands upon previous versions including the "Hydrogen Posture Plan"[54] and the "Hydrogen and Fuel Cells Program Plan"[55] and provides a coordinated high-level summary of hydrogen-related activities across the U.S. DOE. The Fuel Cell and Hydrogen Energy Association published an industry-led "Road Map to a US Hydrogen Economy"[56] that stresses the versatility of hydrogen as an enabler of the renewable energy system, an energy vector that can be transported and stored, a fuel for the transportation sector, heating of buildings, and

52 The study occurred under Navigant Consulting's work authorizations entitled "Hydrogen Research to Enable Deep Decarbonization" and "Energy Storage Technologies and Market Status, California End Use Case Scenarios and Research."
53 https://www.hydrogen.energy.gov/pdfs/hydrogen-program-plan-2020.pdf
54 https://www.hydrogen.energy.gov/pdfs/hydrogen_posture_plan_dec06.pdf
55 https://www.hydrogen.energy.gov/pdfs/program_plan2011.pdf
56 http://www.fchea.org/s/Road-Map-to-a-US-Hydrogen-Economy-Full-Report.pdf

providing heat and feedstock to industry. Guidehouse (formerly Navigant), under a CEC Work Authorization, performed a preliminary assessment of the future uses of hydrogen in California in 2020.

Key Technical and Market Challenges

Currently, most hydrogen is produced from fossil fuels by steam reforming of natural gas, partial oxidation of methane, and coal gasification. For hydrogen to become a major element of the decarbonization efforts in the state, the technology must transition from this fossil fuel-based technology to green electrolytic hydrogen produced from renewable energy. One challenge is the cost of methods for green hydrogen conversion is several times the cost of the fossil fuel-based systems. New innovations are needed in the conversion process used to generate green hydrogen so equipment costs and conversion costs can be lowered substantially. Where small systems are currently operating that validate the process can be implemented successfully, more innovative solutions that take advantage of creative optimization protocols and designs that are simple to manufacture and operate will be needed in the future. Additionally, hydrogen storage is a bulky and expensive process that requires large space or the ability to store the hydrogen under high pressure or very low temperatures. New solutions are needed that can compress and store the hydrogen under more cost-competitive conditions.

Green hydrogen must compete with other solutions like long-duration energy storage, battery-based EVs, and technology solutions that have existing infrastructure. However, because of the expected growth and expansion of renewable technologies, green hydrogen may offer a flexible alternative for distributing and storing energy. Green hydrogen may be generated at a central location and piped to customer sites, bulk delivered in tanks to customer sites, or users can directly generate their own hydrogen at their customer site providing new options for the development of a green-hydrogen infrastructure. More research is needed to assess how hydrogen-based solutions can compete with alternative technology solutions in our future decarbonized world.

Renewable green electrolytic hydrogen energy-storage systems, focused on electricity in and electricity out, are unable to compete on a roundtrip efficiency basis with leading battery-based energy-storage technologies. However, renewable hydrogen energy systems and opportunities for infrastructure co-deployment offer multiple value streams beyond electricity, such as system-level cost savings, environmental, public health, and energy-efficiency benefits. Monetizing these added value benefits of hydrogen will facilitate deployment.

Equity Considerations

This initiative is a broad analysis across all California demographics and does not have an exclusive focus on under-served communities. However, the CEC envisions the following targeted benefits, if and when green hydrogen is widely deployed.

- Transitioning from grey hydrogen to an increasingly blue and green portfolio of hydrogen fuels will help to deliver the carbon emission reductions needed to achieve California's 2045 energy goals.
- In response to PSPS events and with increasing prevalence of high energy-demand data centers, California is experiencing a surge in the deployment of diesel-fueled back-up generators in stark contrast to state air-quality and energy goals. Hydrogen energy systems that utilize fuel cells and hydrogen generated from renewable resources, may both reduce the need for, and provide an alternative to, diesel-fueled generators.

6. Valuation of Investments in Electricity Sector Resilience

Description

This initiative would contribute to the development of methods for valuation of the public benefits (including economic, public health, and other societal benefits)[57] of customer and grid resilience investments, such as microgrids, distributed generation, and storage. As a starting point, this research would include analyses of recent historical weather-related events and other situations (e.g., PSPS events) that have precipitated power outages as a basis for understanding the types of impacts that could be valued in the context of climate resilience by state and local governments. It would also evaluate the distribution of these events among ratepayers, with particular consideration of equity concerns and impacts on Disadvantaged Vulnerable Communities (DVCs), as defined by CPUC for the climate-vulnerability context.[58]

Methods for valuing these investments would reflect the impacts on ratepayers from loss of power and benefits of improved reliability and avoidance of outages, with particular emphasis on capturing impacts for under-resourced communities. Clarifying the public benefits of resilience investments is critical to properly incentivizing deployment of customer and grid resilience measures. Research gaps include valuation of past extreme weather-related outages (such as PSPS events and heat wave-related interruptions) and development of a conceptual framework for the value

57 In addition to the primary guiding principle that EPIC shall provide electricity ratepayer benefits, defined as promoting greater reliability, lower costs, and increased safety, CPUC Decision 12-05-037 includes societal benefits and economic development among a set of complementary guiding principles for EPIC. Also, Decision 12-05-037 finds that applied research and development should include activities that address environmental and public health impacts of electricity-related activities among other topics.

58 In the context of CPUC's adaptation rulemaking, DVCs include the 25 percent highest-scoring census tracts according to the CalEnviroScreen, all California tribal lands, census tracts with median household incomes less than 60 percent of the state median income, and census tracts that score in the highest 5 percent of pollution burden within CalEnviroScreen, but with unreliable public health or socioeconomic data that preclude assignment of CalEnviroScreen score. For more information on DVCs and adaptation planning, see https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M345/K822/345822425.PDF.

of resilience investments that captures public benefits on time scales relevant to GRCs and longer-term (20-30 years) adaptation planning.

Anticipated Impact

A valuation of measures promoting customer and grid resilience would support development of a conceptual framework to assist policymakers in addressing resilience needs. The outcome of this research could be used, for example, to support development of a tool that would assist CEC in targeting research demonstrations to highest value applications. It would also provide investor-owned utilities (IOUs) and the CPUC with a foundation for considering benefits of resilience investments in the context of GRCs and longer-term planning. Enabling utilities to integrate valuation of resilience measures into GRCs as well as into longer-term planning, such as 20-30 year time horizons considered in adaptation planning, is critical to allowing IOUs to make appropriate investments to protect resilient and reliable electricity service. For example, without a basis for integrating resilience investments into GRCs, IOUs would have a limited basis for making or recouping resilience investments. Additionally, CPUC's decision on Phase 1, Topics 4 and 5 of the Adaptation Rulemaking, adopted in August 2020, requires IOUs to do extensive engagement of DVCs to support development of adaptation plans that prioritize investments in these communities. This research would complement research that IOUs are expected to undertake to provide substantial support for understanding climate-related impacts to DVCs as well as the value of investments to protect these communities.

Primary Users and Beneficiaries

CPUC, CEC, IOUs, energy technology industry stakeholders, Governor's Office of Planning and Research, DVCs, and under-resourced communities

Metrics and Performance Indicators

- Use of valuation frameworks by state and local agencies to incorporate public benefits into adaptation planning

- Use of valuation frameworks by IOUs to support customer and grid resilience investments and to inform their obligations to prioritize DVCs in the context of climate change
- Use of valuation frameworks by under-resourced communities in pursuit of funding to support customer and grid resilience

Value Chain	**Program Area(s)**
Grid operations/market design	Applied research & development

Background

Although issues related to extreme weather and other challenges to California's grid have created strong interest in microgrids and other resilience investments, California's state and local agencies currently lack a standardized approach for quantifying value-of-resilience (VOR). The lack of a standardized VOR method could impede investments—or alternately, lead to sub-optimal or misplaced investments—in customer and grid resilience measures. The need to understand and appropriately value public benefits of resilience investments has emerged repeatedly in public workshops, including IEPR workshops related to microgrids as well as climate adaptation workshops.

Research Themes and Policy Priorities Addressed

This initiative supports the **resilience** theme by helping to develop an empirically grounded methodological basis for valuing resilience investments.

Previous Research

The need for this research is an outgrowth of EPIC's applied research on climate vulnerability and resilience options for the electricity sector. Other organizations have conducted relevant research. For example, the Clean Coalition – a California non-profit – recently conducted a limited inquiry into the value of resilience for various tiers of customers. Also, the University of California, Santa Barbara examined the impacts of such a valuation approach on incentivizing microgrids in California. The National Associated of Regulatory Utility Commissioners provided (in 2019) an overview of the use of various approaches to valuing resilience of distributed energy resources (DERs).

Additional studies and papers have been led by the National Renewable Energy Laboratory (NREL), Institute of Electrical and Electronics Engineers, and CPUC staff.

Key Technical and Market Challenges

Currently, there is no commonly accepted basis for incorporating VOR into public agency and IOU decision-making frameworks for resilience investments. This may result in sub-optimal investment in both customer and grid resilience measures. For example, investment decisions may not maximize net public benefits or may not meet objectives for equitable distribution of benefits from resilience investments.

Equity Considerations

This research is intended to deliver broad benefits across all California demographics. It would however include an emphasis on DVCs by investigating the impacts of resilience investments on low-income and disadvantaged communities—who are among the DVCs defined by CPUC's adaptation rulemaking and identified in a decision adopted in August 2020 for special consideration in IOU adaptation planning.

7. Vehicle-to-Building Technologies for Resilient Back-up Power

Description

This initiative seeks to accelerate development, deployment, and commercialization of plug-in electric vehicles (PEVs) and charging equipment capable of powering critical loads in homes and buildings during electric grid outages (referred to as vehicle-to-building or "V2B" technologies). The initiative will explore demonstrations with publicly and/or privately owned vehicles and facilities (e.g., municipal transit buses) powering community buildings (e.g., emergency shelters) as well as private vehicles powering individual residences to evaluate both individual and community resilience applications.

The initiative structure reflects recent decisions in Rulemaking 17-07-007 by seeking innovations in one of two groups: 1) V2B solutions that are compliant with existing

Rule 21 language in which an appropriately certified off-vehicle smart inverter is used; and 2) V2B solutions that are not covered in existing Rule 21 language but have been approved for pilot projects, which rely on the on-vehicle inverter for power conversion and conditioning. Each approach has tradeoffs in complexity, cost, and near-term pathway to deployment that would be evaluated through this initiative. Projects would pursue cost reductions and demonstrate key safety and performance requirements of V2B technologies through hardware and software development, integration, manufacturing scale-up, and demonstration activities. Successful projects would advance products to commercialization that enable V2B with equal performance and lower cost than available zero-emission back-up power alternatives and could inform development of future policies and programs that accelerate zero-emission vehicle deployment.

Anticipated Impact

This initiative would increase individual and community resilience while supporting the state's goals for rapid transportation electrification by accelerating development of products that allow PEVs to provide back-up power to homes and buildings. The core technologies developed, such as efficient bi-directional power electronics hardware and open standards-based charger monitoring and control systems, would be transferable to a variety of vehicle-grid integration use cases, helping to maximize the benefits of simultaneous transition to zero-emission transportation systems and electric sector decarbonization. Projects would build partnerships among automakers, PEV drivers, and utilities, and build confidence in V2B technology capabilities, helping accelerate commercialization of V2B and vehicle-grid integration technologies. Experience in the demonstrations would also directly inform Rule 21 updates for streamlined interconnection processes enabling the use of PEVs as distributed energy resources (DERs).

Primary Users and Beneficiaries

PEV charging equipment manufacturers, PEV charging service providers, and automakers are the primary technology developers targeted for this initiative. PEV owners would benefit from the products developed by enabling their vehicle to act as a controllable DER that enhances their energy resilience, with secondary benefits for utilities and IOU ratepayers achievable through more efficient utilization of existing electric infrastructure.

Metrics and Performance Indicators

- Number of homes, buildings, and individuals with access to zero-emission back-up power provided by PEVs during grid outages (duration)
- Power and energy provided to building and home loads during real and simulated outages (kW/kWh)
- Cost of zero-emission back-up power and energy ($/kW and $/kWh) provided by PEVs
- Number of new V2B commercial product offerings developed by vehicle and equipment manufacturers

Value Chain:	**Program Area(s)**:
Demand-side management	Applied research & development Technology demonstration & deployment

Background

As California pursues a rapid transition to zero-emission transportation systems,[59] PEVs will contribute a growing fraction of load on the state's electric system. Most PEVs have significant flexibility in charging schedule, and the battery capacity of commercially available models is growing, potentially making them a low-cost DER that can contribute to individual, community, and electric system resilience without sacrificing driver mobility. The scale of this potential resource will grow as more PEVs come onto California's roads; a preliminary analysis funded by CEC suggests that PEV charging

59 EO-N-79-20 established the statewide target for 100 percent of passenger car and truck sales to be zero emission beginning in 2035, with all medium- and heavy-duty vehicle sales being zero-emission by 2045 where feasible. Available at: https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-text.pdf.

may contribute up to 4,000 MW of charging load by 2035.[60] There is a critical opportunity to develop technologies that take advantage of unused battery capacity in PEVs to provide a flexible, low-cost DER that delivers resilience benefits to both individuals and communities. Simultaneous electrification of other end uses such as industrial processes and residential heating will also reinforce the need for new loads to act as grid assets and limit stress on the electric grid.

Research Themes and Policy Priorities Addressed

This initiative fits principally within the **resilience and reliability** theme by supporting development and demonstration of low-cost alternatives to stationary storage or diesel back-up generators that can power critical loads during outages, including PSPS events. The initiative indirectly supports **decarbonization** by helping accelerate transportation electrification through the creation of additional resilience benefits that further incentivize adoption as well as through reduction of uncertainty and cost to deploy PEV charging infrastructure.

The initiative responds to numerous policies and recent decisions, because V2B spans efforts related to transportation electrification, DER interconnection, and vehicle-grid integration, including the following examples.

- EO-N-79-20 establishes targets for 100 percent of passenger vehicle and truck sales being zero-emission by 2035 followed by 100 percent of medium- and heavy-duty vehicles by 2045 where feasible.
- R.18-12-006 "Development of Rates and Infrastructure for Vehicle Electrification" includes extensive discussion of V2B for resilience in the recent proposed decision (November 13, 2020) on SB 676 and vehicle-grid integration strategies as well as in the draft Transportation Electrification Framework.
- R.17-07-007 "Streamlining Interconnection of Distributed Energy Resources and Improvements to Rule 21" includes clarifications on V2B interconnection

60 Preliminary results from EVI-Pro 2. Available at: https://efiling.energy.ca.gov/getdocument.aspx?tn=234215.

procedures for off-vehicle inverter-based systems as well as encourages utility piloting of on-vehicle inverter-based systems.

Previous Research

V2B technology has been the subject of applied research and development and technology demonstrations over the past five years in California and globally. The Joint Agencies Vehicle-Grid Integration Working Group final report published in June 2020 identified near-term priority use cases that can provide value to PEV drivers and ratepayers with the goal of comparing these to conventional DER such as stationary storage.[61] Although lack of data has prevented quantitative comparisons, the Working Group provided recommendations for a variety of V2B demonstration activities that can build stakeholder confidence and reduce barriers to widespread market adoption of grid-supportive PEV charging. V2B for resilience applications was also selected as a near-term, high-priority research area in the Draft DER Research Roadmap prepared for CEC by Guidehouse.[62]

Previous investments by the CEC, U.S. DOE's Vehicle Technologies Office, California's IOUs, and other research organizations have evaluated and improved bi-directional charging hardware; communications interfaces between vehicles, chargers, and electric grid systems; and networked and local controls systems. V2B technologies have been tested in laboratory settings and demonstrated at controlled sites, such as the UC San Diego Microgrid. Recent product announcements for off-vehicle inverter-based systems that meet necessary safety and performance requirements demonstrate early commercialization activity; however, these systems generally have higher cost and complexity and are not widely available. The EPIC Policy + Innovation Coordination Group highlighted several recent CEC projects advancing V2B technologies in its

61 Final Report of the California Joint Agencies Vehicle-Grid Integration Working Group. June 2020. https://gridworks.org/wp-content/uploads/2020/07/VGI-Working-Group-Final-Report-6.30.20.pdf
62 Draft DER Research Roadmap available at: https://efiling.energy.ca.gov/GetDocument.aspx?tn=233081&DocumentContentId=65563

October 22, 2020 workshop on vehicles as a source of back-up power, prioritizing this topic for coordination between EPIC program administrators in 2020.[63]

Key Technical and Market Challenges

Despite improvements in V2B technologies and enabling policies, actual product availability, customer enrollment, and utilization remain limited. Technology improvements in both hardware and software for V2B technologies will be required to reduce costs and support widespread adoption alongside PEV deployment. Today, there are limited commercial offerings of V2B systems, which are expensive in large part because of the need for an off-vehicle smart inverter. Technologies that utilize on-vehicle power conversion equipment do not require off-vehicle inverters and are expected to have significantly lower cost. However, demonstration of smart inverter functionalities and safety requirements using on-vehicle power conversion equipment are required to build automaker experience and capabilities into PEV product offerings. Most major automotive manufacturers do not currently offer or warranty vehicles for V2B capabilities, although there are some early international examples (such as adoption of vehicle-based back-up power in Japan using CHAdeMO standards in Nissan vehicles).

Equity Considerations

Twenty-five percent of the demonstration project funding in this initiative will be reserved for under-served communities. By including demonstrations of V2B technologies at community buildings (e.g., emergency shelters) and with publicly funded vehicles such as transit and school buses, this initiative would help bring benefits to those who do not personally own PEVs. In these projects, researchers will be encouraged to identify and partner with individuals and organizations representing under-resourced communities, such as those that experience frequent PSPS events or suffer air-quality and health impacts of fossil-fuel back-up generation. Additionally, in

63 Presentations from the October 22, 2020 workshop as well as background information on the Transportation Electrification workstream of the Policy + Innovation Coordination Group can be found at: https://epicpartnership.org/transportation.html

the long-term, this initiative would accelerate development and deployment of technologies that provide resilience benefits and that will drive down cost and open up V2B opportunities to a broader cross-section. Demonstration activities located in and benefitting under-resourced communities would receive additional preference in proposal scoring.

8. Offshore Wind Energy Technologies

8a. Manufacturing and Testing of Floating Offshore Wind Energy (FOSW) Components

Description This initiative would spur innovation in manufacturing, assembly, and installation processes for FOSW component(s), such as substructure, foundation, and support substructure, and demonstrate at a pilot scale to validate the expected benefits, such as levelized cost of energy (LCOE) reduction. This initiative would demonstrate manufacturing techniques and processes locally to make large-scale deployment of FOSW structures more feasible and cost-effective and to deliver greater economic benefits for the state.
Anticipated Impact California has an opportunity to become one of the first global manufacturing centers for FOSW infrastructure. The continued development of floating offshore component designs could be particularly advantageous, attracting established companies in the FOSW market to move their operations to California or partner with California manufacturers. Investing in FOSW manufacturing in the state would also help decrease the costs of transportation of FOSW components, generate additional economic benefits, and create jobs. California is also well-positioned to become an international leader in floating platform development across the Pacific. The development of FOSW

will provide a valuable resource for achieving the goals of SB 100 and for supporting grid reliability, as FOSW has a daily generation profile that complements solar.

Primary Users and Beneficiaries

Project developers and technology developers.

Metrics and Performance Indicators

- Achieve LCOE for FOSW lower or equal to $75/MWh.
- Advance the FOSW components to technology readiness level (TRL) 7-8.

Value Chain	**Program Area(s)**
Generation	Applied research & development

8b. Inspection and Monitoring Systems for FOSW Applications

Description

This initiative would test and validate monitoring systems for FOSW components that support reduction of installation and operation and management (O&M) costs and increase commercial readiness. This could, for example, use suites of sensors and advanced computer algorithms to predict failures and allow planned interventions that reduce downtime and operation costs. O&M accounts for 25-30 percent of the total lifecycle costs for offshore wind farms and represents a major hurdle for the OSW industry. Data from OSW farms currently in operation show that technological advancements in O&M can reduce the number of required site visits from five per year to three per year, delivering important cost savings and improved safety for maintenance workers.

Anticipated Impact

Remote monitoring could reduce the number of trips from land to offshore facilities for monitoring and inspection, with potential for significant cost savings and worker safety improvements.

Primary Users and Beneficiaries

Project developers and project operators.

Metrics and Performance Indicators

- Achieve LCOE for FOSW lower or equal to $75/MWh.
- Advance the FOSW inspection and maintenance tools to TRL 7-8.

Value Chain	**Program Area(s)**
Generation	Applied research & development

8c. Environmental Research for FOSW Development

Description

This initiative would develop tools or methods for assessing and monitoring the environmental impacts associated with the assembly and operation of FOSW components, such as impacts to biodiversity, habitat, and coastal upwelling.

Anticipated Impact

Innovative environmental research would help identify potential risks to wildlife and habitat from FOSW deployment and enable mitigation and management of potential impacts. Approaches that combine the environmental monitoring with FOSW operations monitoring could further improve cost-effectiveness.

Primary Users and Beneficiaries

Project developers, project operators, and permitting agencies.

Metrics and Performance Indicators

- Advance the FOSW inspection and maintenance tools to TRL 7-8.
- Adoption of practices by state and federal environmental agencies based on research results.

Value Chain	**Program Area(s)**
Generation	Applied research & development

8d. Pilot Demonstration of FOSW Technology

Description

This initiative would pilot demonstrate a FOSW system and components offshore of California to identify unique hurdles and associated solutions for commercial-scale FOSW projects. This initiative may leverage U.S. DOE efforts to fund California projects focused on implementing innovative technologies for FOSW at pilot or full scale.

Anticipated Impact

The pilot demonstration of FOSW technology in California can help provide important insights for deployment at scale and help position the state as an early global leader in manufacturing and production of FOSW technologies. Public financial support is critical to promote further market development in California and would help identify hurdles and research needs to make FOSW technology competitive.

Primary Users and Beneficiaries

Project developers, project operators, state agencies, and interested groups.

Metrics and Performance Indicators

- Achieve LCOE for offshore wind energy lower or equal to $75/MWh.
- Advance the FOSW technology to TRL 7-8.

Value Chain	Program Area(s)
Generation	Applied research & development

Background

California has a massive 112 GW of accessible OSW energy. Nearly all of this potential (96 percent) is located in coastal waters deeper than 60 meters, where traditional OSW technologies are not suitable.[64] These deeper waters require floating wind technology, which is advancing toward commercialization in both Europe and Asia. California coastal

64 https://www.boem.gov/sites/default/files/environmental-stewardship/Environmental-Studies/Pacific-Region/Studies/BOEM-2016-074.pdf

OSW resources have diurnal characteristics that are complementary to the state's solar resource, where the average peak generation occurs at the end of the day and evening.[65]

FOSW is a subset of OSW and refers specifically to systems that use floating technology (OSW as used in subsequent discussion below refers to offshore wind in general). The average LCOE of FOSW projects is estimated at approximately $230 per MWh as of 2019 and is expected to decrease to about $75/MWh by 2030, according to the U.S. DOE. However, the true cost of commercial-scale FOSW remains unknown, as commercial-scale floating wind farms have not yet been deployed in the United States. The global FOSW project pipeline is about 5 GW, with just 46 MW installed and the rest in varying stages of development.[66] While case studies from these projects could provide overarching lessons for California, they would not be indicative of potential cost in the state due to a variety of factors, including differences in government support, funding mechanisms, interconnection policies, transmission development, among other factors. Fixed (non-floating) OSW projects remain a more costly alternative to land-based wind, solar, and conventional generation in most locations. The first commercial-scale FOSW projects are projected to have a higher LCOE than fixed turbines due to higher substructure costs, less-established supply chains and manufacturing processes, and greater financial and technical uncertainty. For the proposed FOSW R&D initiatives, the CEC is adopting the U.S. DOE's projected cost reduction ($75/MWh) as a cost target to improve cost-competitiveness.

65 Gilman et al 2016. Gilman, P., B. Maurer, L. Feinberg, A. Duerr, L. Peterson, W. Musial, P. Beiter, J. Golladay, J. Stromberg, I. Johnson, D. Boren, A. Moore. 2016. National Offshore Wind Strategy: Facilitating the Development of the Offshore Wind Industry in the United States. U.S. Department of Energy and Bureau of Ocean Energy Management. Available at http://energy.gov/sites/prod/files/2016/09/f33/National-Offshore-Wind-Strategyreport-09082016.pdf.

66 Research and Development in Offshore Wind in California, 2020. https://ww2.energy.ca.gov/2020publications/CEC-500-2020-053/CEC-500-2020-053.pdf

Research Themes and Policy Priorities Addressed

The FOSW initiatives fall within the research themes of **decarbonization** and **resilience and reliability**. FOSW technology will provide another significant source of renewable energy that can help meet the state's decarbonization goals. This emerging technology will allow California to exploit the generally higher and steady wind resources offshore, to potentially achieve GW-scale projects. This makes FOSW an important addition to the portfolio of renewable technologies available to decarbonize the economy. Advances in technology innovation, O&M approaches, supply-chain efficiencies, and logistical synergies with closely linked markets increase cost competitiveness. Additionally, the expected daily generation profile of FOSW is also complementary with that of solar generation, helping meet loads that cannot be easily met with solar and thereby enhancing grid reliability.

Previous Research

In recent years, the U.S. DOE has prioritized two key areas of R&D for FOSW technology innovation: 1) design of turbine platforms, anchors, and moorings; and 2) simulation and testing to accelerate learning with limited demonstrations. Currently, the U.S. DOE is funding the University of Maine to install and test a pilot FOSW project of up to 12 MW using a concrete semi-submersible foundation design at a test site off Monhegan Island, Maine.

The National Offshore Wind Research and Development Consortium (NOWRDC) – a non-profit partnering with DOE, several states along the East Coast, and independent and private entities – has three research pillars: 1) OSW plant technology advancement, which includes floating structure mooring concepts for shallow and deep waters; 2) OSW power resource and physical site characterization; and 3) installation, O&M, and supply chain solutions. In 2019, the NOWRDC selected seven projects addressing challenges on floating structure mooring concepts for shallow and deep waters.

The CEC released the EPIC solicitation "Next Wind," which funded four agreements on OSW focusing on increasing generation productivity, reducing the LCOE, addressing potential wildlife impacts through real-time and remote monitoring, and understanding and mitigating potential impacts to sensitive species and habitat. Furthermore, two EPIC-funded studies identified R&D opportunities for OSW: the "Utility-Scale Renewable Energy Generation Technology Roadmap"[67] and the "Research and Development Opportunities for Offshore Wind Energy in California" study.[68]

Key Technical and Market Challenges

Innovation is key to reducing the LCOE of FOSW, including advancements in floating substructures, anchoring and mooring components, and inspection and monitoring strategies. Previous studies indicate that manufacturing of the turbine, floating substructure, and anchoring systems make up the main portion of the life cycle cost of a FOSW project, followed by O&M and installation costs. R&D efforts can advance innovative technologies and manufacturing approaches for anchors, mooring, and cabling, including inter-array cabling webs and dynamic cabling. For instance, the development of synthetic mooring lines (nylon, polyester, aramid, etc.) could improve performance and reduce O&M costs and susceptibility to fatigue in dynamic ocean environments. The development of manufacturing approaches that optimize existing supply chains, local materials, and manufacturing or assembly solutions may improve operational efficiency, reduce LCOE, ease logistics challenges, and promote local labor and economic development.

Limited data are available on floating technology performance and project development at commercial scale. Currently, there is no FOSW platform system in the world that operates in an environment directly comparable to California's northern and central coasts in terms of wind, waves, and water depth. Developing technologies to ease

67 Schwartz, Harrison, Sabine Brueske. 2020. Utility-Scale Renewable Energy Generation Technology Roadmap. California Energy Commission. Publication Number: CEC-500-2020-062. https://ww2.energy.ca.gov/2020publications/CEC-500-2020-062/CEC-500-2020-062.pdf
68 Sathe, Amul, Andrea Romano, Bruce Hamilton, Debyani Ghosh, Garrett Parzygnot (Guidehouse). 2020. Research and Development Opportunities for Offshore Wind Energy in California. California Energy Commission. Publication Number: CEC-500-2020-053. https://ww2.energy.ca.gov/2020publications/CEC-500-2020-053/CEC-500-2020-053.pdf

installation and O&M costs in extreme wind and wave conditions that would prevent regular repair and maintenance, including remote monitoring and robotic maintenance, is key to reducing the LCOE. Floating platform technology has been proven to be technically viable, but because it is still relatively new, few large-scale operational projects exist globally.

Additional data collection is needed on the potential impacts of OSW projects on commercial fisheries, wildlife, migration, and offshore ecosystems in California. Both environmental and fishing stakeholders cautioned against attempting to transfer knowledge from studies conducted in other countries. Stakeholders see potential biodiversity impacts in California as more significant than those in the North Sea or other global fixed-turbine project areas due to California's high level of biodiversity and key coastal migratory routes. To solve specific OSW challenges with fish, birds, and marine mammals, stakeholders suggest that data collection on ecosystems and migratory routes is needed. Research on advanced mitigation technologies like smart curtailment (using sensors to manage turbine rotation to mitigate bird-strike risk), sonar deterrence (to reduce entanglement of marine animals), and robotic mooring line cleaning (to prevent lines from snaring nets and other debris that can trap sea mammals) could help reduce wildlife impacts.

Equity Considerations

This initiative is expected to benefit Californians broadly. Potential benefits of OSW development for California communities – including under-resourced communities – include jobs in coastal regions, economic growth, and enhanced electricity reliability and affordability by balancing and complementing solar generation. The potential of OSW to provide power during the night could also reduce dependence on natural gas power plants that are disproportionately located in under-resourced communities. Successful deployment of OSW and the resulting increase in clean and renewable generation will help the state reach its clean energy goals, delivering an array of human health and climate change mitigation benefits. However, the full macroeconomic benefits from

OSW development in California have not yet been fully assessed; such assessment would provide better insights on the value propositions for OSW projects.

9. Entrepreneurial Ecosystem

9a. California Sustainable Energy Entrepreneur Development (CalSEED)

Description This initiative would build upon the CalSEED Initiative efforts established under the first three EPIC Investment Plans. The small-scale funding provided by the CalSEED Initiative gives entrepreneurs starting capital to develop their ideas into proof-of-concepts and early prototypes. This level of funding fills a crucial niche in the financing landscape for clean energy entrepreneurs because venture capital firms have decreased their level of investment at this level over the past several years. The goal of this initiative is to allow the CalSEED Initiative to reach more entrepreneurs throughout California.
Anticipated Impact CalSEED is often the CEC's first touch point for many clean energy start-up companies, providing a small amount of funding that can set up these companies to be successful when applying to larger funding opportunities and attracting interest and investment from the private sector. In addition, CalSEED provides a path for Intellectual Property developed at research institutions to spin out of the lab and into commercial ventures. Through November 2020, CalSEED has provided funding for 91 start-up companies. These companies have gone on to receive $37.40 million in public funding and $28.36 million in private investment. The CEC expects this impact to continue with the proposed funding in this interim plan.

Primary Users and Beneficiaries

Clean energy entrepreneurs, research institutions, private investors, project developers and systems integrators, energy solution providers.

Metrics and Performance Indicators

- Follow-on Private Investment
- Follow-on Public Funding
- TRL
- Commercial Readiness Level (CRL)

Value Chain	**Program Area(s)**
Grid operations/market design Generation Transmission Distribution Demand-side management	Applied research & development

9b. Bringing Rapid Innovation Development to Green Energy (BRIDGE)

Description

BRIDGE seeks to: 1) accelerate early-stage research funded by the federal government and the CEC through the later-stages of the TRL spectrum; 2) help start-up companies minimize the time between when their successful publicly-funded project ends and the time new public funding becomes available; and 3) mobilize more early-stage capital in the clean energy space by providing non-dilutive, matching investments in promising clean energy companies alongside investors and commercial partners. This provides increased support for the most promising clean energy technologies that have already attracted interest from the market as they are developed and continue their path to market adoption. For example, Ubiquitous Energy transitioned federally funded research on organic photoactive material at MIT into a commercial venture to develop solar power-generating glass. Under BRIDGE, Ubiquitous Energy has been able to develop and install the first public demonstration of its power producing window façade prototype and commissioned its first pilot production line in Redwood City. In addition, Ubiquitous Energy has received national attention, such as being featured in Forbes and appearing on CNN Business.

Anticipated Impact

This initiative will leverage and build on the CEC's and federal government's significant investments in basic and applied research and provide an accelerated pathway for that research to transition out of universities and national laboratories and into commercial ventures. New inventions are often incubated for years at research institutions as the science is advanced and potential energy applications are identified. In addition, federal agencies such as National Science Foundation and U.S. DOE's Advanced Research Projects Agency – energy (ARPA-e) support technologies at the earlier stages of the TRL spectrum but have limited ability to support these technologies further down the TRL spectrum. BRIDGE provides a streamlined pathway for the CEC to pick up these technologies and move them quickly through the TRL stages. For example, with BRIDGE funding SkyCool Systems has been able to move quickly to pilot demonstrations following research developed at Stanford and funded by ARPA-e. SkyCool Systems has developed a thin film coating and rooftop cooling panel that passively reject heat to the sky. "Depending on the application and climate conditions, the technology could cut the energy used to cool structures by 10 to 70 percent."[69] In addition, this initiative will help reduce delays faced by technology innovators that result from a lack of secure funding sources and send a strong signal to private investors regarding the technology's merits given the higher requirements for selection into BRIDGE.

69 Temple, J. 2017. "A Material That Throws Heat into Space Could Soon Reinvent Air Conditioning", *Massachusetts Institute of Technology* (*MIT*) *Technology Review,* www.technologyreview.com/2017/09/12/149205/a-material-that-throws-heat-into-space-could-soon-reinvent-air-conditioning/

Primary Users and Beneficiaries

Clean energy start-up companies, skilled workers, universities and national laboratories, federal research programs, private investors

Metrics and Performance Indicators

- Private investment leveraged in BRIDGE award
- Follow-on private investment; company employment growth
- TRL and CRL achieved at the end of the project

Value Chain	Program Area(s)
Grid operations/market design Generation Transmission Distribution Demand-side management	Applied research & development

9c. Realizing Accelerated Manufacturing and Production (RAMP)

Description

This initiative provides financial assistance to help clean energy entrepreneurs successfully advance their emerging best-of-class innovative technology to the Low-Rate Initial Production (LRIP) stage, also referred to as Manufacturing Readiness Level 8. LRIP is the first step in making the transition from highly customized hand-built prototypes, which are used for performance testing and vetting the production process, to the final mass-produced end product produced in the Full-Rate Production phase. Ten companies were selected for the first RAMP cohort and the CEC expects to award the next RAMP cohort in early 2021. RAMP has already helped start-up companies scale-up production in California. Caban Systems is developing a software-enabled modular energy storage system for telecommunication towers and other critical infrastructure. This technology offers a cleaner, more robust, low-maintenance alternative to diesel back-up generators that can also withstand harsh environments

and be monitored and operated remotely; a key feature for telecommunication tower owners and operators since many towers are located in remote locations. Under RAMP, Caban has been able to increase production capacity of its energy storage solution from 1 unit per month to 1 unit per day, enabling the company to meet customer demand for its energy storage product. Sepion Technologies, another RAMP awardee, is developing a nanoporous membrane separator for lithium batteries. Sepion's separator overcomes the limitations of current ceramic-based separators, enabling lithium batteries that have higher energy density, longer life spans, are less prone to thermal runway, and don't require cobalt. Under RAMP, Sepion has been able to increase production of its advanced battery membrane from 0.01 square meters per hour (m^2/hr) to 6 m^2/hr, which would be able to supply up to 24 EV battery packs (50 kWh).
Anticipated Impact This initiative would help start-up companies scale-up their production levels to: 1) improve their per-unit costs; 2) increase their production capacity to meet customer demand; and 3) increase their production yields; and 4) demonstrate to private investors that they have overcome manufacturing challenges that make clean energy technologies a risky proposition. In addition, this initiative would help increase the number of clean energy manufacturing jobs in California. To date, the first cohort of RAMP companies have collectively hired 65 skilled workers since their RAMP award started and are expected to hire another 181 by the time their RAMP projects have completed. These companies collectively employed 55 skilled workers prior to their RAMP award. This would represent a 336-percent increase in the number of skilled workers employed by these companies. **Primary Users and Beneficiaries** Clean-energy start-up companies, California-based manufacturers, skilled workers, customers

Metrics and Performance Indicators

- Number of companies that reach Manufacturing Readiness Level 8
- Follow-on private investment
- Increase in production capacity and yields
- Increase in manufacturing jobs at start-up companies

Value Chain	**Program Area(s)**
Grid operations/market design	Market facilitation
Generation	
Transmission	
Distribution	
Demand-side management	

9d. Market Research

Description

This initiative would conduct market research on emerging technologies that are expected to replace incumbent technologies or create new markets not served by incumbent technologies. It could also provide executive-level expertise to companies to accelerate product commercialization and secure financing. Market research conducted under this initiative would, among other activities, identify:

- Near- and mid-term markets where emerging technologies can be competitive with incumbent technologies:
- Specific cost components that account for the overall cost of emerging technology solutions; and
- Technical and cost targets that need to be met – both at the cost-component level and the overall technology package – for these emerging technologies to gain market traction.

Anticipated Impact

This initiative would provide clear targets for public and private decision-makers to use for investment decisions. In addition, this initiative would provide targets for researchers and clean-energy start-up companies to drive toward with their innovations.

Primary Users and Beneficiaries

Researchers, clean-energy start-up companies, government agencies, industry, investors

Metrics and Performance Indicators

- Number of reports and publications that market research conducted under this initiative referenced and cited
- Number of EPIC solicitations that are informed by the market research conducted under this initiative.

Value Chain	Program Area(s)
Grid operations/market design Generation Transmission Distribution Demand-side management	Market facilitation

9e. Cost Share for U.S. DOE Funding Opportunities

Description

This initiative would provide cost share to California-based organizations applying to funding opportunities issued by the U.S. DOE that are consistent with the goals and objectives of EPIC. The CEC Cost Share for U.S. DOE Funding Opportunities ("Federal Cost Share") solicitation has been a key tool in promoting the efficient use of ratepayer funds and attracting federal funding to California. Through this solicitation, the CEC has provided $10.9 million in EPIC funding, which has leveraged $ 112.8

million in federal funding. For example, the CEC awarded $3 million in EPIC funds which helped a research consortium led by Lawrence Berkeley National Lab win a $100-million award from U.S. DOE to establish an Energy-Water Desalination Hub.

Anticipated Impact

This initiative would help California-based organizations meet the cost-share requirements of funding opportunities by U.S. DOE and be more competitive in the selection process. In addition, this initiative will help attract federal funding to California as well as promote the efficient use of ratepayer funds.

Primary Users and Beneficiaries

National laboratories, private clean energy companies, California universities, non-profit clean energy organizations

Metrics and Performance Indicators

- Amount of federal funding leveraged
- Amount of federal funding brought to California

Value Chain	Program Area(s)
Grid operations/market design Generation Transmission Distribution Demand-side management	Applied research & development, Technology demonstration & deployment

Background

Clean energy entrepreneurship is vital to realizing California's ambitious energy and climate change policy goals and providing benefits to electric ratepayers. Clean energy start-up companies have become the primary market segment responsible for developing and introducing new technology solutions into the electricity sector – especially as large energy providers have found it more cost effective to strategically partner with or acquire start-up companies with new technology solutions than to develop their own in-house R&D activities.

The CEC launched the Entrepreneurial Ecosystem in 2016 to better support clean energy entrepreneurs developing breakthrough technology solutions. The Entrepreneurial Ecosystem consists of direct funding initiatives along with entrepreneurial support services to stage-gate new technologies through the energy innovation development pipeline. Through the Entrepreneurial Ecosystem, the CEC has supported 223 clean energy start-up companies. These companies hold more than 418 patents, employ more than 1,081 individuals, and have gone on to receive over $426 million dollars in follow-on funding.

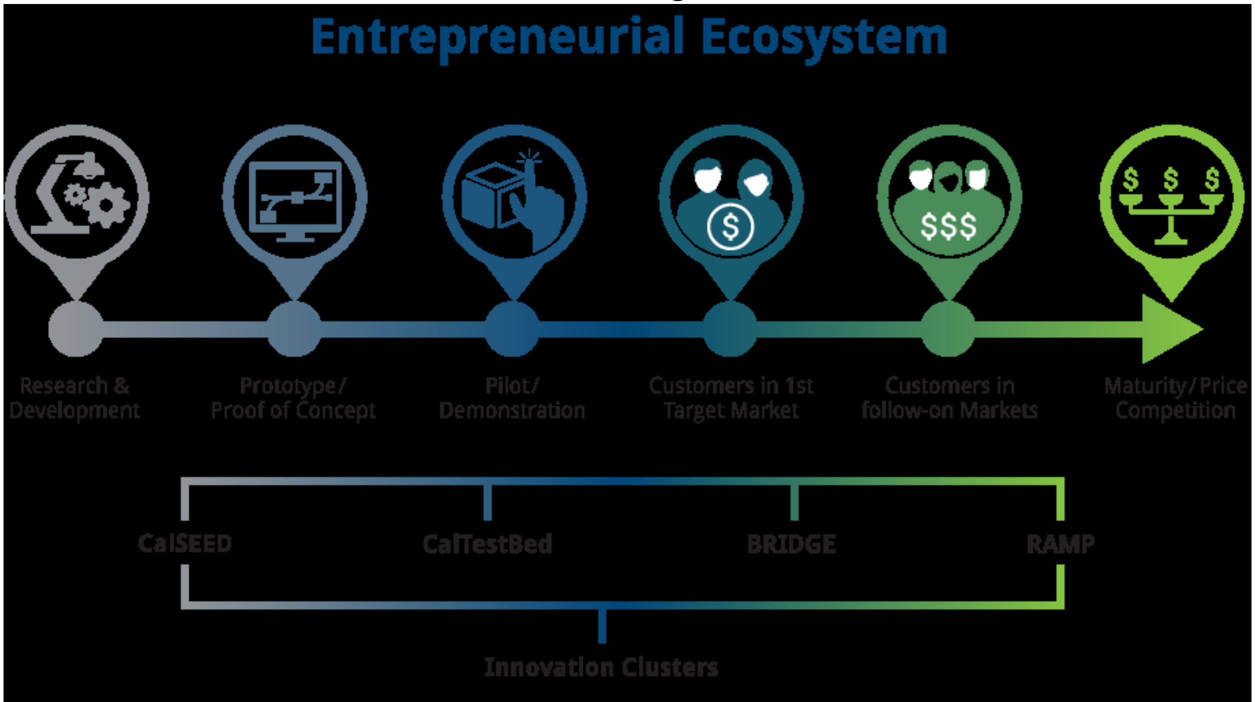
Research Themes and Policy Priorities Addressed

The CEC through EPIC has taken significant steps to bring private investment back into clean energy innovation. EPIC has provided certainty to the private sector by providing funding at key stages in technology development that the private sector is not able to fund. Also, by providing consistent funding and a commitment to R&D funding, EPIC has provided increased confidence to researchers and private sector investors to pursue clean energy ventures. More importantly, the CEC has provided validation to the private sector of a new energy technology's merits. The primary driver has been the Entrepreneurial Ecosystem developed under EPIC to mobilize California's vast resources around clean energy entrepreneurship and make new clean energy ventures investable. Supporting **entrepreneurship** fosters research under the themes of **decarbonization** and **resilience and reliability** as well. The CEC's Interim Plan initiatives would continue to provide funding for clean energy entrepreneurs targeted at key stages in development of their technologies.

Previous Research

Following the steep drop in private investment for early-stage clean energy technologies and companies, a number of studies and organizations identified the need to reimagine the existing model for delivering clean energy technologies to the market. Starting in 2016, the CEC through EPIC has led a series of programs called the Energy Entrepreneurial Ecosystem, shown in Figure 1, that collectively provide this new model.

Figure 1. The Entrepreneurial Ecosystem Mobilizes and Organizes a Wide Array of Stakeholders and Resources Throughout the State to Provide Clean Energy Startups with the Technical and Business Support Needed to Advance Their Technologies



As mentioned above, CEC's California Sustainable Energy Entrepreneur Development Initiative (CalSEED) is a small grant program under EPIC that provides help to early stage California clean energy startups to bring their concepts and prototypes to market. More information is available at: www.calseed.fund. CalTestBed is a voucher program that provides clean energy entrepreneurs access to nearly 30 testing facilities throughout the state to conduct independent technology testing and validation. More information is available at www.caltestbed.com. Bringing Rapid Innovation Development to Green Energy (BRIDGE) is an EPIC solicitation program that provides clean energy startups that have previously received federal or CEC funding to continue working on their technologies without waiting for a new public funding opportunity or pausing to raise private funding. Realizing Accelerated Manufacturing Production (RAMP) is an EPIC solicitation program that supports clean energy entrepreneurs' transition from one-off prototype manufacturing to an initial pilot production line capable of conducting low-rate initial production. Finally, the Innovation Clusters are a set of four EPIC-funded projects that collectively provide entrepreneurial support services —such as laboratory equipment and buildings, business plan development, and connections to investors —throughout the state.

Key Technical and Market Challenges

Clean energy entrepreneurs developing new technologies face a number of technical and market challenges on their way to commercializing their inventions, including:

- *Lack of early-stage private sector investment*. In 2013, a year before the first CEC EPIC awards were made, venture capital and other early-stage private sector investors largely pulled out of the clean energy innovation sector after a series of failed investments.[70] In a July 2016 Energy Initiative paper,[71] Massachusetts Institute of Technology reported that venture capital investment had dropped to $2 billion, down from a peak of $5 billion in 2008, after investors learned through firsthand experience that new energy technologies have longer development timelines and higher capital requirements than software start-up ventures. Additionally, a National Academies of Sciences study found that, "many investors at the venture and similar investment stages lack the technical capability to assess which energy technologies hold the greatest potential."[72]
- *Significant gaps between funding awards*. For even the most promising energy innovations, researchers and technology developers typically require multiple rounds of public funding to advance their technology to a state where it can attract interest and investment from the private sector. However, the time between when a successful publicly funded project ends to the time new public funding opportunities become available can be years apart. Even under a best-

70 Gaddy, Benjamin, Varun Sivaram, Francis, O'Sullivan 2016. Venture Capital and Cleantech: The Wrong Model for Clean Energy Innovation. https://energy.mit.edu/wp-content/uploads/2016/07/MITEI-WP-2016-06.pdf.
71 Ibid.
72 National Academies of Sciences, Engineering, and Medicine. 2016. The Power of Change: Innovation for Development and Deployment of Increasingly Clean Electric Power Technologies. Washington, DC: The National Academies Press. https://doi.org/10.17226/21712

case scenario, this delay in funding can significantly slow the pace of a new technology's development.

- *Transitioning from prototype to production-scale.* Startups that attempt to scale-up face several hurdles when moving from prototype to production, including a series of new design challenges that impact a host of innovations. Start-up companies typically lack the practical manufacturing experience to successfully move their energy technology innovation to production. Moving a technology into production requires understanding of a wholly different set of considerations than the initial technology development, including material selection, supply-chain management, and assembly steps.
- *Information gaps on technical and cost targets that need to be met for market traction.* New technologies must exceed specific technical and cost requirements to gain traction over incumbent technologies in existing markets or to enable new markets. Currently, market and government actors have little to no visibility on what technical and cost targets need to be met, the cost components that contribute to the overall costs, and the near-term market applications where emerging technologies can be competitive with incumbent technologies. As a result, private investors and government funders have little information on which to make more targeted investment decisions. In addition, researchers and technology developers need information and analysis on the key pain points customers face so they can design technology solutions that provide a compelling value proposition over incumbent technologies.

Equity Considerations

Equity has been a key focus and priority in the CEC's design and implementation of the Entrepreneurial Ecosystem. For example, the CEC set a minimum funding target in CalSEED for diverse businesses such as minority-, women- and lesbian, gay, bisexual, transgender, queer (LGBTQ)-owned businesses, and businesses in a disadvantaged community or rural part of the state. In addition, the CEC designed the Innovation Clusters to support geographic diversity and ensure entrepreneurs in every part of the state have access to incubator and accelerator programs. Further supporting geographic diversity, CalSEED applicants are grouped and selected based on their geographic region. The four innovation clusters have all made equity a part of the incubator/accelerator programs they offer. This includes:

- Providing mentoring to clean energy start-up companies on how they can make equity part of their businesses' core values as they grow and scale.
- Conducting outreach to bring clean energy entrepreneurs from diverse and underrepresented backgrounds into the incubator/accelerator program.
- Targeting start-up companies with technologies that can specifically benefit under-resourced communities and low-income customers.
- Ensuring incubator services are available and accessible to clean energy entrepreneurs in rural locations of the state.

This has enabled the four clusters and CalSEED to attract an additional $3.8 million in federal funding to expand their respective programs in under-resourced parts of the state. CalSEED has committed to providing $4 million of funding specifically to focus on equity within the clean energy and entrepreneur space. The CEC's RAMP Program is also increasing the number of manufacturing jobs in California, helping to provide skilled jobs. The initiatives under the Entrepreneurial Ecosystem will continue to support equity in entrepreneurship including the following:

- CalSEED will continue to set a minimum target for the amount of funding that goes to entrepreneurs from underrepresented groups such as minority-, women- and LGBTQ-owned businesses, and businesses in a disadvantaged community or rural part of the state.
- CalSEED will continue to group and select proposals based on their geographic region in California. This will continue to ensure geographic diversity of CalSEED recipients.
- Applicants to RAMP will be evaluated in part on the number of skilled manufacturing jobs in California they are creating.

- The Market Research initiative will conduct customer discovery to identify what features and functionality low-income customers want in clean energy technology solutions and what specific pain points low-income customers face that prevent access to clean energy technologies. In addition, the Market Research initiative will identify cost and performance targets that need to be achieved for clean energy technologies to be affordable for low-income customers.